ePARTNER FOR SELF-CARE

HOW TO ENHANCE eHEALTH WITH
PERSONAL COMPUTER ASSISTANTS

ePARTNER FOR SELF-CARE

HOW TO ENHANCE eHEALTH WITH
PERSONAL COMPUTER ASSISTANTS

PROEFSCHRIFT

ter verkrijging van de graad van doctor
aan de Technische Universiteit Delft,
op gezag van de Rector Magnificus prof.dr.ir. J.T. Fokkema,
voorzitter van het College van Promoties,
in het openbaar te verdedigen op vrijdag 19 juni 2009 om 10:00 uur

door **Olivier Anne BLANSON HENKEMANS**

doctorandus in de Informatie- en Communicatiewetenschappen
geboren te Amsterdam

Dit proefschrift is goedgekeurd door de promotoren:
Prof.dr. M.A. Neerincx

Copromotor: Dr.ir. C.A.P.G. van der Mast

Samenstelling promotiecommissie

Rector Magnificus, voorzitter
Prof.dr. M.A. Neerincx, Technische Universiteit Delft, promotor
Dr.ir. C.A.P.G. van der Mast, Technische Universiteit Delft, copromotor
Prof.dr. C.M. Jonker, Technische Universiteit Delft
Prof.dr. E.J. Krahmer, Universiteit van Tilburg
Prof.dr. H. de Ridder, Technische Universiteit Delft
Prof.dr. W.A. Rogers, Georgia Institute of Technology
Prof.dr. J.H.M. Schonk, Leiden Universitair Medisch Centrum

Graphic Design: Aard Bakker, Amsterdam
E-Mail: Olivier.BlansonHenkemans@TNO.nl

Research was supported by SenterNovem Innovative Research Program Human-Machine Interaction (IOP-MMI).

ISBN 978-90-813811-3-0

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1

INTRODUCTION

1.1 SELF-CARE

John (aged 55), enjoys his full time profession as an attorney. However, combining his demanding career with his social and family life leaves little room for maintaining a healthy lifestyle and as a result he is overweight. Lately, he has experienced some trouble with his health, such as frequent urination, sweating and changing moods. He visits his physician, who sends him to the policlinic. Test results indicate that he suffers from diabetes type II. The physician strongly recommends him to maintain a healthy diet, perform exercise regularly, use domestic medical instruments, take medication, and regularly check in with medical specialists. Key issues for John are combining these self-care with his daily tasks while maintaining a good quality of life.

Like John, numerous people suffer from being overweight and lifestyle related diseases, such as diabetes type II. Worldwide, approximately 1.6 billion people are overweight or obese, 170 million people suffer from diabetes, and cardiovascular diseases are the number one cause of death. In the Netherlands, overweight impacts approximately 45% of the population and diabetes affects approximately 3% of the population and is expected to rise to 9% (Baan & Poos, 2005; Kreijl & Knaap, 2004; Statistics Netherlands (CBS), 2007a, 2007b).

Studies have indicated that more patient engagement in the care process could reduce these figures, e.g., (Leventhal, Weinman, Leventhal, & Phillips, 2008; Maes & Karoly, 2005). Consequently, to address this situation, there is a gradual shift from a passive relationship between the individual patient and the health care system towards a more independent, self-determining and active position wherein the emphasis lies on achieving self-care objectives.

Self-care consists of activities undertaken by individuals, families, and communities with the intention of preventing disease, limiting illness, and restoring health (Leventhal & Mora, 2005). It aims at educating and increasing the patient's intrinsic motivation, which in turn can lead to stimulation of maintaining a healthy lifestyle and adhering to medical treatment (Maes & Karoly, 2005). Examples of self-care activities are maintaining a healthy diet (European Food Safety Authority (EFSA), 2006; Kreijl & Knaap, 2004), performing physical activities (Brooks, Butte, Rand, Flatt, & Caballero, 2004; Kemper, 2004), using medical instruments, such as glucose and blood pressure meters, setting personal goals (Gollwitzer & Oettingen, 2008) and increasing health literacy (Morrow et al., 2006). Other terms used for increase and maintenance of health are disease self-regulation and self-management, but for this dissertation we have chosen the term self-care for its clarity and conciseness.

To performing self-care activities optimally, the patient needs to cope with various issues (Clark et al., 1991). They are faced with psychosocial problems, such as stigmatism, and they need to manage daily living according to their financial and social conditions. Moreover, patients require sufficient knowledge about their condition and its treatment, performance of condition management activities, and application of the necessary skills to maintain adequate psychosocial functioning (Barlow, Sturt, & Hearnshaw, 2002). In short, to meet with these requirements, patients need to be provided with relevant medical information and support for developing self-care skills., i.e., problem solving, decision making, resource utilization, forming of a patient/health care provider partnership, and taking action (Lorig & Holman, 2003).

1.2 eHEALTH SERVICES

By deploying Information and Communication Technology (ICT) in the medical domain, eHealth can address the issues in self-care. In 2001, Eysenbach defined eHealth as *an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies* (Bodenheimer & Grumbach, 2003; Eysenbach, 2001). There are various examples of eHealth services (Table 1.1), such as websites that offer information on healthy diets and physical activities; websites that enable people to keep diaries of their diet and physical activities; mobile applications that enable people to keep diaries of their diet; and domestic eHealth technologies supporting aging in place, such as remote communication tools and monitoring with domestic medical instruments.

TABLE 1.1

Selection of Dutch eHealth Services Related to Health and Lifestyle

eHealth Service	Name	Reference
Informative websites	Voedingscentrum	www.voedingscentrum.nl
	RIVM	www.rivm.nl
	Nederlands Instituut voor Sport en Bewegen	www.nisb.nl
Online diet diaries	DieetInzicht	www.dieetinzicht.nl
	Valtaf	www.valtaf.nl
	Voedingscentrum	www.voedingscentrum.nl
	Weightwatchers	www.weightwatchers.nl
Online activity diaries	30 minuten bewegen	www.30minutenbewegen.nl
	Map my Run	www.mapmyrun.com
Mobile applications	Slim-Easy	www.slim-easy.nl
Domestic eHealth	Philips Home and Care lab	www.research.philips.com technologies/misc/homelab
	Stichting Smart Homes	www.smart-homes.nl
	TNO/TU Delft Experience Lab	www.usabilitytesting.nl
	Health Buddy	www.sananet.nl

eHealth can have multiple benefits. Besides decreasing lowering health care costs (Eysenbach, 2001), it can help deal with the estimated increased increase demand for patients' care and nursing care for older adults. As listed in Figure 1.1, it is predicted that from 2000 until 2025 there is a strong increase in patients with chronic diseases and that as these patients are growing older, by 2020 the demand for older adults nursing care will double (Berg Jeths, 2004). eHealth can alleviate this demand through virtual coaches, which motivate patient to adhere to the diverse treatments (Fogg, 2003), domestic medical instruments for self-monitoring (Rogers, Essa, & Fisk, 2007), personalized medical encyclopedia for developing health literacy and supporting informed medical decision-making (Lippa, Klein, & Shalin, 2008; Morrow et al., 2006), and telemonitoring systems enabling aging in place (Mynatt & Rogers, 2002).

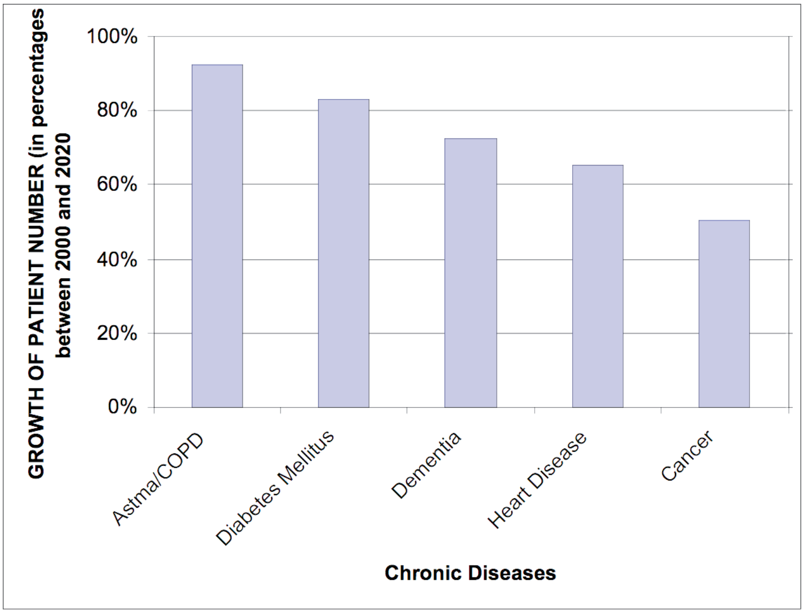


FIGURE 1.1

Expected growth of top five chronic diseases, between 2000 and 2020, in the Netherlands (Berg Jeths, 2004).

1.3 SUPERASSIST PROJECT

To address the current issues in the health care service and study how to promote eHealth, TNO, Delft University of Technology and Leiden University Medical Center established the SuperAssist project. These research institutes are also developing models for the support of self-care. This is done by integrating Computer Assistants, or so called ePartners, in eHealth services for personalized support. Furthermore, the project's industrial partners, Benchmark, DieetInzicht, Philips Research, and Science & Technology, bring in their technology and contribute to the development and validation of SuperAssist elements. The goal of the project is to develop a model for personalized assistance of self-care (Haan, Blanson Henkemans, & Ahluwalia, 2005).

In the SuperAssist model, illustrated in Figure 1.2, the Computer Assistant monitors the patient environment and medical record and provides personalized feedback styles on the self-care activities. The goals of the assistant are to support self-care by stimulating medical adherence and to facilitate adequate use of medical instruments. Furthermore, personalization refers to tuning the representation of the Computer Assistant and the feedback style it applies to the user. We will elaborate on this in the next section, Human-Computer Assistant Interaction.

In addition to providing local support, the patient's Computer Assistant collaborates with other assistants in the architecture to mediate the (remote) communication between patient and specialists. On the one hand, the different assistants mediate the communication between the patient and the medical specialists, such as general practitioner, internist and dietitian, who supervise the patient's health. The medical specialists' assistant offers support by managing the patient file, communication with colleagues and daily care activities, and offering expert medical information. On the other hand, the assistants mediate the communication between the patient and the technical specialist, who supervises the medical instruments' "health". The technical specialist's assistant offers support by managing service appointments and providing expert instrument information. In our model we include different actors. The aim of self-care is to stimulate patient empowerment, i.e., independence, self-determination and involvement. Consequently, in our research we will focus on the computer assistance of the patient.

Besides addressing the social and medical issues, researching and modeling eHealth with Personal Computer Assistants can have scientific benefits. We base our research on Human Computer Interaction (HCI) theories and concepts related to feedback (McLaughlin, Rogers, Fisk, & Essa, 2005), appearance

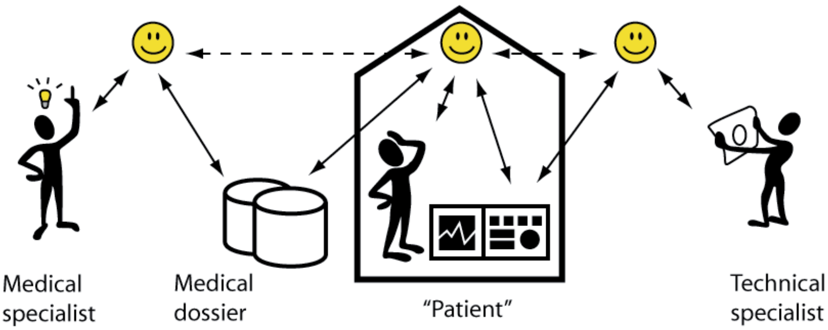


FIGURE 1.2

SuperAssist Model: Personal Computer Assistants, illustrated as smiley faces, supporting patient self-care at home and mediating communication with remote medical and technical specialists.

(Looije, Cnossen, & Neerincx, 2006), personalization (Alpay, Overberg, & Zwetsloot-Schonk, 2007), adaptive interfaces (Grundy & Hosking, 2002), and persuasive technology (Fogg, 2003). Our findings could help answering how these aspects can contribute to the improvement of HCI. Moreover, with the research on Personal Computer Assistants, we aim at obtaining insights in ICT support for other professional domains dealing with complex tasks environments, such as naval (Grootjen, Neerincx, & Veltman, 2006), space (Neerincx et al., 2006), and police surveillance (Streefkerk, Esch-Bussemakers, & Neerincx, 2007). Due to the complexity, these domains require dynamic and adaptive support and it is essential to know how a Personal Computer Assistant could facilitate this.

1.4 HUMAN-COMPUTER ASSISTANT INTERACTION

In the SuperAssist model, eHealth leans strongly on the interaction between human users and Personal Computer Assistants. In accordance with Human-Computer Interaction (HCI) theories, it evolves around the users involved, i.e., patient, medical specialist and technical specialist, and their requirements (Benyon, Turner, & Turner, 2005; Dix, Finlay, Abowd, & Beale, 1998). Consequently, it requires assessment of user, context, tools, Human Factors, user interface, and developing process. The latter is concerned with design, evaluation and implementation (Preece, 1994) and is discussed separately in section 1.5, User-Centered Design.

1.4.1 *User, Context and Tools*

It is becoming more common for Information and Communication Technology (ICT) systems to be integrated in the user's environment ubiquitously. The system monitors the user through multiple sensors in different environments and interacts through various computer devices simultaneously (Weiser, 1991). Consequently, eHealth can vary with the user, in the context and with the use of tools. First, it can be used by patients individually or in collaboration with other actors, such as medical specialist, and for various goals, such as monitoring self-care or for mediating communication. Second, it can be used in different situations, such as at home, in the hospital, or in the outdoors, and on different moments. Moreover, complex and critical situations can burden the user's physical and cognitive resources (Barnard, 1987). For example, when John suffers from a hyperglycemic attack, due to a high glucose level, he will experience blurred vision and fatigue, which in turn can negatively affect the human-computer interaction. During the interaction special attention should be given to type of interaction medium, e.g., text, images and sound, and the presentation of information so it can be easily understood and processed. Third, it can include different tools such as a desktop computer, mobile device, or smart board. As an illustration, we envision the following scenario: John inquires with the medical specialist for medical information, which is important for his personal quality of life. This takes place in his home environment, by using his mobile phone, personal computer and glucometer. In turn, the medical specialist wants to optimally fulfill one of her many daily tasks in the highly paced and professional environments of the hospital. Here she is using the common phone and computer and a variety of medical devices integrated in the hospital environment.

1.4.2 *Human Factors in Human-Computer Assistant Interaction*

The success of Human-Computer Assistant Interaction also depends on how well the design is geared to Human Factors (Alpay et al., 2004; Czaja et al., 2006; Slegers, 2006). Again, John does not only deal with his health complications. As an older adult, he may also experience a decrease in physical and cognitive abilities, such as hearing and short term memory. Also, he has specific personality traits, such as level of motivation, extraversion, and locus of control that partly determine his preference (Graziola et al., 2005; Kim & Schniederjans, 2004).

The general process and outcome measures addressed in Human Factors are related to the users' personal characteristics and their influence on systems' safety, comfort, ease of use, and productivity. Consequently, Human Factors can be used to set requirements during the design phase and outcome measures in the evaluation process. For example when the interaction with the Personal Computer Assistant is satisfying, motivational and educational, John will presumably perform his self-care more effectively and consistently. Accordingly, we will explore the effect of different Human Factors personal characteristics, including demographics, cognitive abilities and personality traits on the use of eHealth with Personal Computer Assistants. Section 2.3.2 elaborates further on these measures

1.4.3 *User Interface: Appearance and Feedback Style*

User, context, tools and Human Factors have implications for the way the user perceives and operates the system and manages relevant data. Accordingly, the assistant's appearance and feedback style determine how successful the interaction will be for specific use, context and users. As listed in Table 1.2, the use of different interface modalities can contribute to the usability of systems (Jacko et al., 2004; Rosson & Carroll, 2002). However, in some cases it is possible that use of multiple sensory channels at once can distract the user if the task he is performing requires a high focus within a single sensory channel. Consequently, it is important to select the interface modalities that fit best with the task. This is especially the case when designing a multimodal interface for critical situations, when cognitive resources are taxed and attention needs to be dispersed between different sources. The use of animated personas and robots can stimulate and improve the quality of the interaction (Krahmer, Swerts, Theune, & Weegels, 2002). For example, research on the use of a robot for the support of diabetes treatment showed that children preferred interacting with a socially intelligent interface over a simple text interface (Looije et al., 2006).

Modality	Advantage	Disadvantage
Text	Information and concepts can be explained in a detailed and unambiguous manner.	Interaction is slow due to large amount of texts. It can lead to overwhelming and possibly abandoning task. Lay out (size, font, color) is crucial
Images	Graphics can be used to illustrate and visualize information and concepts that would otherwise be very difficult to explain in text.	Inadequate design of graphics can have a strong negative impact on user satisfaction. Colors can be missed by colorblind users.
Sound and speech	Natural way of interaction. Can be used to accentuate user's actions and focus user's attention.	Can work distractingly, depending on task. Due to time lengthiness, often unsuitable for time critical interaction.

TABLE 1.2

Examples of advantages and disadvantages of different interaction modalities.

In addition, the use of different feedback styles can support tuning the interaction to different users and situations (Bandura, 1997; Bass, 1960; Kahai, Sosik, & Avolio, 2004; Payne, Sycara, Lewis, Lenox, & Hahn, 2000; Somech, 2005). As defined in Table 1.3, the Computer Assistant can apply a cooperative feedback style (i.e., it has a coaching character, aims at explaining, informing, and educating the user, and expects high participation of the user), or a directive feedback style (i.e., it has more of an instructing character, aims at brief reporting, and expects low participation of the user). In summary, the cooperative feedback style is more oriented towards user satisfaction and long-term development. The directive feedback style is more oriented towards quick and efficient problem solving in cases of health anomalies. Moreover, to combine the advantages of both assistant feedback styles, the style can be adapted to the users' situations. This is relevant when users are caught in a critical situation and cognitive resources are diminished or need to be divided between different tasks (Gaillard, 2003).

	Cooperative Feedback style	Directive Feedback style
Assistant Characteristics	Coaching Educating Advising Oriented towards satisfaction and long-term development	Directing Reporting Dictating Oriented towards quick problem solving
User Demands	High participation level Committing	User is mostly uninformed Complying
Advantages	User learns new competencies Develops understanding Better performance in long-term User-assistant complementing	User needs few competencies Better performance in short-term Vigorous acting
Disadvantages	Assistant support can become tedious and patronizing	User is vulnerable to making mistakes when called upon User loses idea of control

TABLE 1.3

Comparison of Computer Assistant Feedback Styles

For self-care adherence, the patient has to integrate and perform self-care activities in his or her daily life. Developing these new habits requires goal setting and achieving in the long-term. Also when relapsing in old habits, the patient requires empathy to increase self-efficacy and should be persuaded to persist in the activities. To realize this, it may be beneficial to combine different Computer Assistant feedback style and appearance types. For example, a Persuasive Computer Assistant could provide support with a cooperative feedback style, according to a motivational interviewing process, and increase effectiveness and satisfaction. Also it could be represented by an animated avatar, which also uses its nonverbal communication, e.g., facial expression, to underline its feedback.

1.5 USER-CENTERED DESIGN

The most acknowledged developing method of Human-Computer Interaction is the user-centered design approach (Garrett, 2003; Righi & James, 2007; Vredenburg, Isensee, & Righi, 2002). Principally, development is driven by the total user experience (Maguire, 2001). User feedback on requirements, goals, and tasks is iteratively gathered and applied by the multidisciplinary design teams throughout the process (Murray et al., 1998) Although this approach can be timely and costly, it assures that the technology fulfils its intended purpose in the environment in which it will be used. Also, it is especially effective for innovative technology where audience characteristics and habits are not well defined (Preece, Abras, & Maloney-Krichmar, 2004). As a result, applying a user-centered design approach is beneficial for the development of eHealth with Computer Assistants. It facilitates defining the relevant user requirements, concerning the use of domestic medical instruments, adherence to self-care objectives, general usability of eHealth services and the issues of persuasive technology. Moreover, by applying these requirements according to the Cognitive Engineering (CE) approach, as described in Section 1.5.5, it can drive the iterative design and evaluation process.

1.5.1 *Use of Domestic Medical Instruments*

Self-care depends on the patient's awareness of his or her health condition, which is assessed through the of use domestic medical instruments, such as blood pressure and glucose meters. For example, self-measurement of glucose level can help to assess the current condition and the (in)effectiveness of self-care activities. At times, the patient will encounter technical problems which disrupt the measurements and can lead to counteractive results. The patient can resolve these complex and critical situations by troubleshooting, consisting of the search for likely causes of faults through a potentially erroneous problem space of possible causes (Schaafstal, Schraagen, & van Berlo, 2000). Moreover, the user can be guided by a remote technical specialist.

1.5.2 *Medical Adherence*

According to the World Health Organization, the average rate of adherence across diseases and medications is just 50% (Sackett & Snow, 1979; World Health Organization, 2003a). Increasing the likelihood of medical adherence can be supported by addressing motivation, self-efficacy, health literacy and goal setting (Gollwitzer & Oettingen, 2008; Lorig & Fries, 2006; Maes & Karoly, 2005; Suchman, Botelho, & Walker, 1998; United States Department of Health and Human Services, 2000). Motivation is the drive to perform healthy behavior, enter disease treatment, try to change an unhealthy behavior, follow a treatment regimen, or engage in other health-relevant behavior (Williams, 1998).

Self-efficacy is an individual's estimate or personal judgment of his or her own ability to succeed in reaching a specific self-care goal. The perception of self-efficacy is crucial for human behavior, i.e., for determining the beginning and maintenance of behavior and for its persistence (Kneckt, 2000). Finally, health literacy is the degree to which individuals have the capacity to obtain, process, and understand basic health information and services needed to make appropriate health decisions. An assessment of health literacy is important to infer how medical treatment is integrated in the patient's life (Morrow et al., 2006). Moreover, it is required to set and achieve goals, which are beneficial and feasible (Barrett, 2007).

1.5.3 *Usability*

Usability is the extent to which users can employ technology to perform tasks and achieve a particular goal. It is typically measured through three variables, namely effectiveness, efficiency and satisfaction (Nielsen, 1993; Norman, 1988; Shneiderman, 1987). ISO standards define these factors as the following (ISO 9241-11):

- **Effectiveness is the accuracy and completeness with which users achieve certain goals. Indicators of effectiveness include quality of solution and error rates;**
- **Efficiency is the relation between the accuracy and completeness with which users achieve certain goals and the resources expended in achieving them. Indicators of efficiency include mental effort, task completion time and learning time;**
- **Satisfaction is the users' comfort with and positive attitudes towards the use of the system.**

These factors identify the requirements when specifying or evaluating usability in terms of measures of user performance and satisfaction.

1.5.4 *Persuasive Technology*

As described, the goal of eHealth is to improve self-care behavior. Persuasive technology, which deals with interactive computing systems designed to change people's attitudes and behaviors (Fogg, 2003), can offer great benefits to the medical domain. Persuasive systems can work around the clock and offer care to the patient non-stop. They offer anonymity, which may stimulate the patient to be more open about his or her health condition. They can manage great amounts of data and use various modalities. Consequently, they can use accurate, significant numbers to suggest recommendations and present them in the modality most comprehensible to the user. Finally, the system is scalable and ubiquitous. Thus, information is easily replicated and distributed through multiple devices in the user's environment.

Despite the advantages mentioned, research on persuasive technology is relatively new and there are several concerns to overcome (Eng, 2001). For example, due to its novelty, persuasive technology intentions may be obscured to the user. For example, a certain lifestyle change may be recommended in an attractive way, but the underlying reason may be unclear to the patient. Also, the system can elicit emotions but is not sensitive to them. Consequently, when it comes to influencing lifestyle, the system can not always genuinely meet the need for empathy for the trade-offs patients deal with daily. Finally, when dealing with systems that offer support of medical care, they will be perceived as an authority. Still, the computer can not be held responsible the way medical specialists are. Considering these benefits and risks, we need to conduct empirical research on the use of persuasive technology before actually applying it.

In summary, when developing eHealth with Personal Computer Assistants, we need to take into account these User-Centered factors. eHealth should stimulate medical adherence, support of medical instrument usage and be tailored to the user. Moreover, when aiming at stimulating self-care, persuasive technology can be beneficial, but also entails certain risks.

1.5.5 *Cognitive Engineering Approach*

As an extension of the User-Centered Design method, the Cognitive Engineering approach, i.e., applying cognitive psychology and Human Factors to human interface design, has been successfully applied for developing adaptive support in complex environments (Neerincx & Lindenberg, 2008). Examples are support systems for naval and space domains, characterized by the involvement of different actors with different needs in various situations. The medical domain shares these characteristics and we will apply the Cognitive Engineering (CE) approach as our research methodology, which is discussed in Chapter 2.

The Cognitive Engineering (CE) approach guides conducting Work Domain and Technical Support Analyses and mapping out the Design Specifications. The analysis and specifications are used for iteratively designing and evaluating Personal Computer Assistant prototypes. In turn, the evaluation results are used to refine and augment the initial Specifications. Finally, CE can help addressing medical ethical issues of eHealth evaluation. By replacing theoretical parts of the Work Domain into practical applications, step by step, and iteratively evaluating them, it can facilitate the transition from conducting Smart Home Lab studies with healthy adults using Wizard of Oz prototypes, which are seemingly autonomous, but driven by the experiment leader, to conducting field studies with patients with fully working eHealth services

1.6 PROBLEM STATEMENT

As discussed in this chapter, the health care service involves a variety of users with different needs in different situations. Thus, for optimal support, developing eHealth requires personalization, i.e., individually tailoring and interactively delivering information (Tufano & Karras, 2005). Personalization could be achieved through implementing Personal Computer Assistants, which offer support tuned to the users' self-care activities and personal characteristics (McLaughlin, Rogers, & Fisk, 2004; Rogers et al., 2007). Characteristics that influence technology use concern cognition (Carroll, 1993; Czaja et al., 2006; Fisk, Rogers, Charness, Czaja, & Sharit, 2004), personality traits (Christensen & Smith, 1995; Kneckt, 2000; O'Hea et al., 2005), and context (MacIntyre et al., 2001). Still, personalization is currently insufficient when applied. Also, due to lack of empirical research, it is difficult to define the influence of eHealth with Personal Computer Assistants on self-care in different circumstances (Nooijer et al., 2005; Norman et al., 2007). Consequently, our research question reads:

> *Which Personal Computer Assistant features can enhance eHealth services and support self-care, in relation to troubleshooting of domestic medical instruments and adherence to self-care objectives?*

As listed in Table 1.4, we will empirically study in controlled and real life settings (Pagliari, 2007) the influence of HCI aspects, related to the user, context, tools, Human Factors and Computer Assistant user interface, on self-care process and outcomes. These outcomes and processes, as discussed in the User-Centered Design section, are related to the two self-care aspects of troubleshooting of domestic medical instruments and adhering to self-care objectives. Consequently, we will look at usability, health literacy, motivation and performing daily self-care activities. Concerning the influence of HCI aspects, we will study the effects of different user interface feedback styles and appearances on self-care processes and outcomes. Moreover, we will explore how user differences, context, tools, and Human Factors related to self-care explain variance in this effect.

TABLE 1.4

Studying the influence of user, context, Human Factors and user interface on Personal Computer Assistants of self-care process and outcome measures.

Users, context and tools	**Human Factors**	**Computer-Assistant User Interface**	**Process and outcome measures**
Troubleshooting of domestic medical instruments			
1. Individual patient in critical situation using domestic medical instrument	Demographics, spatial ability, reading skill and speed, Locus of Control and Need for Closure	Cooperative and directive feedback style, text and images	Troubleshooting effectiveness, efficiency and satisfaction
2. Patient and technical specialist in critical situation using domestic medical instruments	Demographics, computer experience, spatial ability, and Locus of Control.	Cooperative and directive feedback style, text and images	Troubleshooting effectiveness, efficiency and satisfaction
Adherence to self-care objectives			
3. Individual patient in normal situation using Digital Diary and virtual patient	Demographics, computer experience, desire for participation, self-efficacy, Locus of Control, and the Big 5 personality traits	Cooperative and directive feedback style, animated avatar	Adherence to care plan, commitment and satisfaction. Performing daily self-care activities
4. Individual patient in normal and health critical situation using Digital Diary, electronic patient record and medical instruments	Demographics, vocabulary, perceptual speed, memory span, spatial ability and Locus of Control.	Adaptive feedback, text and graphics	Self-care effectiveness efficiency and satisfaction, health literacy
5. Individual patient in normal situation using digital Lifestyle Diary	Demographics, Body Mass Index (BMI), computer experience, vocabulary and Locus of Control	Persuasive Computer Assistant, animated avatar	Diary use, i.e., frequency, completeness and motivation, and outcomes, i.e., BMI, lifestyle knowledge, and ease of use

The first study focuses on the patient troubleshooting of domestic medical instruments independently. The patient receives support with different types of feedback styles. Considering the critical nature of the situation, i.e., failures need to be resolved correctly and as quick as possible, and the issues of different interaction modalities as described in Table 1.2, the assistant provides support in text and images. Presumably, the Computer Assistant interface and human factor aspects will influence the troubleshooting process and outcomes. Thus, we will study:

1 *How can a Personal Computer Assistant, applying cooperative and directive feedback styles in text and images, support maintaining and troubleshooting of domestic medical instruments in an effective, efficient and satisfying way?*

Occasionally, the patient cannot solve the problems independently and requires the support of a remote technical specialist. This entails support of collaboration characterized by differences in personal characteristics, i.e., older novice patient and younger technical specialist, and location dispersal. The different users may require different interface types for optimal troubleshooting processes and outcomes. As a result, we will study:

2 *How can Personal Computer Assistants, applying cooperative and directive feedback styles in text and images, support remote collaborative troubleshooting of domestic medical instruments in an effective, efficient and satisfying way?*

In addition to troubleshooting of domestic medical instruments, we focus on Personal Computer Assistants for self-care adherence. Here, the emphasis shifts from effective and efficient action to positive user experience stimulating motivation, self-efficacy, health literacy, and goal setting. Consequently, we will aim at implementing multimodal Computer Assistants that support adherence to daily care activities and we will study:

3 *How can a Personal Computer Assistant, applying cooperative and directive feedback through an animated avatar, support commitment and adherence to daily care activities in a satisfying way?*

Due to their illness, patients can experience health critical situations. For example, diabetics suffer from hypo- and hyperglycemic attacks eliciting trembling, sweating and irritability, which in turn can affect the user's resources and thus the development of health literacy. Besides the above-mentioned interface and Human Factors aspects, different health situations may require different Computer Assistant interface types and we will study:

4 *How can an Adaptive Computer Assistant, applying cooperative and directive feedback in text and images, support normal and health critical situations and contribute to health literacy in an effective, efficient and satisfying way?*

Finally, after answering the previous questions on supporting self-care and carefully determining the benefits and risks of the development of Personal Computer Assistants, we will include actual patients in our study. They set personal lifestyle goals and received support from a Persuasive Computer Assistant, represented by an animated iCat, showing different facial expressions, and providing cooperative feedback following the motivational interviewing concept. Consequently, we will study:

5 *How can a Persuasive Computer Assistant, applying motivational cooperative feedback through an animated avatar support Online Lifestyle Diary use in relation to frequency, completeness, motivation and health outcomes, over a prolonged period of time?*

In addition to conducting qualitative experiments, we will address the technical feasibility of Personal Computer Assistants. This is a prerequisite for integrating the proposed Personal Computer Assistants in the eHealth setting. Following the Cognitive Engineering approach, we will study:

6 *Is it technically feasible to develop an eHealth framework with the proposed Personal Computer Assistants?*

1.7 HOW TO READ THE THESIS

As illustrated in Figure 1.3, this thesis discusses developing eHealth services with Personal Computer Assistant according to the Cognitive Engineering (CE) approach. Part I gives an overview of the methodology, i.e., the application of the Cognitive Engineering approach to the development of eHealth. Also, it discusses the technical feasibility of eHealth with Personal Computer Assistants. Part II discusses the iterative design and evaluation of eHealth with Personal Computer Assistants (PCAs). It covers the effects of different features, namely, feedback styles and appearance on two self-care aspects, namely, troubleshooting of domestic medical instruments and medical adherence. The thesis concludes with a summary of our findings, implications, and recommendations for future research.

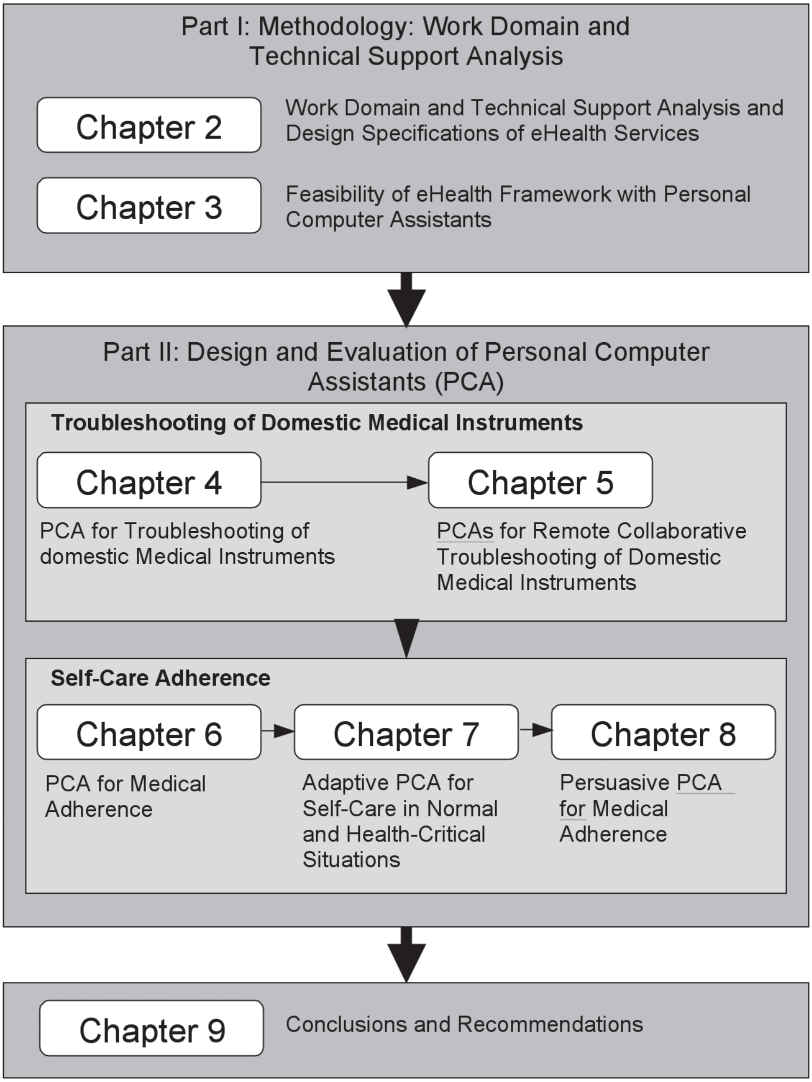


FIGURE 1.3

Dissertation Outline

2

DOMAIN ANALYSIS AND DESIGN SPECIFICATIONS

Personal Computer Assistants tailoring eHealth services to the patients' needs are theoretically beneficial. However, to study how they can positively contribute to the self-care process and outcomes, there is a need for empirical research. This chapter discusses, in accordance with the Cognitive Engineering approach, the Work Domain and Technical Support Analysis and Design Specifications. In later chapters we will apply the analysis for iterative prototyping and evaluating eHealth services with Personal Computer Assistants. This chapter is based on previously published articles.*

* Blanson Henkemans, O.A. Caine, K.E., Rogers, W.A., Fisk, A.D. Neerincx, M.A., & Ruyter, B. de. Medical Monitoring for Independent Living: User-Centered Smart Home Technologies for Older Adults. Med-e-Tel 2007, April 18-20, 2007, Luxemburg, Luxemburg.
Blanson Henkemans, O.A., Lindenberg, J. Mast, C.A.P.G. van der, Neerincx, M.A, & Zwetsloot-Schonk, J.H.M. Incremental and Medically Ethical Design of Usable eHealth Support For Disease Self-Regulation. CIB W084 Building Comfortable and Liveable Environments for All, May 15-16, 2008, Georgia Institute of Technology, Atlanta, GA, United States.

2.1 INTRODUCTION

As discussed in Chapter 1, eHealth requires implementation of personalization to optimally support self-care. Theoretical evidence provides support for the beneficial effects that Personal Computer Assistants can have on eHealth services. Given the right approach, context and implementation process, investment in personalizing eHealth could lead to improved care quality and productivity, which in turn liberates capacity and enables greater access in the healthcare sector (Ahern, 2007; Stroetmann, Jones, Dobrev, & Stroetmann, 2006). However, to date, personalization has received little attention and there is a lack of empirical research on its effect on self-care process and outcomes.

Past studies have shown that applying a Cognitive Engineering (CE) approach, i.e., applying cognitive psychology and Human Factors to human interface design, is beneficial for implementing and evaluating personalization by addressing critical domain and user issues. Specifically, it facilitates, with the use of practical theories and models, design and evaluation of advanced technology tailored to the specific user needs of an application domain (Hollnagel, 2003; Hollnagel & Woods, 2005; Rasmussen, 1986).

Since its introduction, the CE approach deals with iterative design, evaluation and refinement to facilitate development of support adaptable to the user. Initial user requirements guide the design and evaluation of system prototypes. In turn, the results support refinement of the requirements. This approach is ideal for addressing the HCI issues related to users and their complex and dynamic tasks, goals, context and tools. Moreover, it focuses on the user in a specific domain, such as in our case the medical domain. As listed in Table 2.1, examples of Cognitive Engineering methods are Hierarchical Task Analysis, Cognitive Task Analysis, Activity Theory, and Joint Cognitive Systems.

TABLE 2.1:

Examples of Cognitive Engineering Methods

Cognitive Engineering Method (References)	Description
Hierarchical Task Analysis (HTA) (Kirwan & Ainsworth, 1992)	The analysis of what an operator (or team of operators) is required to do, in terms of actions and cognitive processes, to achieve a system goal. It focuses on the structure and order of actions.
Cognitive Task Analysis (CTA) (Hollnagel, 2003)	The analysis of the users' knowledge structures or mental models applied when they perform a task with a specific mechanical or digital tool. A well known example of CTA is GOMS (Card, Moran, & Newell, 1983), which focuses on goals, operators, methods and selection rules.
Activity Theory (Nardi, 1996)	Task and activity are broken down into actions, which are further subdivided into operations. It emphasizes that tools are adjusted during the development of the activity itself and carry with them a particular culture - historical remains from their development.
Joint Cognitive Systems (JCS) (Hollnagel & Woods, 2005)	Combines cognitive characteristics of the human, computer system, and tasks to maximize the human-system performance. Focuses on joint collaboration between human and system whereby the system is goal oriented, adaptive, and operating based on knowledge of and experience with the user knowledge.

Recently, Neerincx & Lindenberg expanded the CE approach by adding a technology perspective, consisting of the incremental implementation concept. The design process starts with drawing a theoretical end model. Step by step, the initially envisioned and simulated technology is, refined and augmented with functioning components (Neerincx & Lindenberg, 2008).

In accordance with the expanded Cognitive Engineering approach, the next sections discuss our research methodology. It discusses the Work Domain and Technological Support Analysis. Based on the analysis, we will determine the Design Specifications used for iterative design and evaluation of eHealth with Personal Computer Assistants.

2.2 COGNITIVE ENGINEERING IN THE MEDICAL DOMAIN

Cognitive Engineering has proven useful for design of ICT support in different complex domains, such as on naval ships and space stations (Neerincx & Lindenberg, 2008). Various international space agencies have plans for manned missions to the moon and Mars. Such missions require technology that empowers the cognitive capacities of human-machine teams during planetary exploration missions to cope autonomously with unexpected, complex and potentially hazardous situations. Neerincx and colleagues designed a Mission Execution Crew Assistant (MECA) that meets with these requirements (Neerincx et al., 2006). The requirements are derived via the above defined cognitive engineering method. Specifically for MECA, this method distinguishes three types of iterations: system-design review, scientific discourse and simulation-based evaluation. The first two iterations provided a set of requirements for distributed human-machine collaboration on Mars, including scenarios and use cases, and a simulation-based evaluation approach for prototypes of future support systems in high-demand situations.

As another example of a high-demand domain, the Royal Netherlands Navy aims at realizing adequate deployment of human and Information and Communication Technology (ICT) resources for the new set of naval missions. This requires a concise and coherent design approach for the development processes of future naval ships. In addition, this approach should incorporate Human Factors knowledge, facilitate the application of new enabling technology and fit to the specific defense context. In response to this requirement, Neerincx & Lindenberg developed Situated Engineering for Adaptive Maritime Aiding Task Environments (SEAMATE) (Neerincx & Lindenberg, 2008). Following the CE approach, the authors progressed through three phases. First, they developed a model of the cognitive task load (CTL) that could be used to harmonize the task demands to the human capacities via task allocation and design of cognitive support. Second, they distinguished current support concepts for harmonization and, based on these concepts, defined a specific set of support functions and support modes as “building blocks” for the adaptive functions in future naval ships. Third, they specified a Technological Design Space (TDS) roadmap with a scope of five to ten years. Over the course of time, they will describe the expected developments of the enabling technology for the adaptive functions. These functions are currently being developed in an iterative process. When system development processes for future naval ships start, SEAMATE can be used to guide the development of the intelligent user interfaces.

The health care service has similarities to the space and naval domains. Due to the involvement of different actors with different needs in various situations, developing eHealth services is equally complex and requires adaptive support. In addition, it deals with medical ethics. Evaluating if eHealth fulfills the requirements, i.e., increasing medical adherence and securing adequate use of medical instruments, is optimal when studies are conducted in the actual application environment. In addition, it has to take place with users for whom using the technology is personally relevant.

In accordance with the Cognitive Engineering approach illustrated in Figure 2.1, this chapter will discuss the Work Domain and Technical Support Analysis, covering self-care, Human Factors, and envisioned technology. Then, the analysis is used as a base for determining the Design Specifications for developing eHealth services with Personal Computer Assistants for the support of self-care, consisting of functions, claims and scenarios. Subsequently, in the following chapters, the Design Specifications are applied for iteratively designing and evaluating eHealth with Computer Assistants prototypes. In turn, the results support the refinement and augmenting of the initial design specifications.

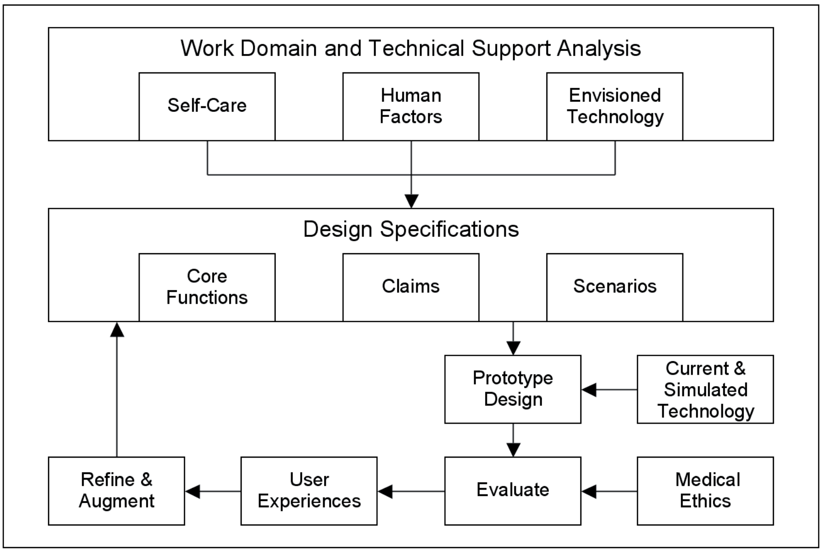


FIGURE 2.1

Cognitive Engineering Approach for developing eHealth services.

2.3 WORK DOMAIN AND TECHNICAL SUPPORT ANALYSIS

Following the projects' aim, i.e., exploring the current issues in the health care service and study how eHealth can alleviate them, we conducted an elaborate work domain and technical support analysis. As listed in Table 2.2, we performed web searches, literature reviews, document analyses, and interviews. During the analysis, we focused on current care processes, Human Factors, and existing and future eHealth services.

TABLE 2.2
Overview of domain analysis activities.

Activity	Goal	Domain
Web search	Find relevant projects and products	Dutch projects on patient self-regulation and ICT (e.g., thromboses, hemophilia, heart failure, diabetes, asthma)
Literature research	Find relevant publications	Papers, projects, research groups, journals, conferences
Document analyses	Assess domain requirements	Protocols, medical dossiers, regulations, statistics
Interviews and observations	Assess domain requirements	Medical specialists, patients, patient associations, industry, policlinics

To validate our analysis, the findings were presented and reviewed during bi-annual multi-disciplinary workshops. During the workshops, the scientific partners present their research results and brainstorm about ongoing activities. The members have different backgrounds, e.g., medical specialists, psychologists, interaction designers, computer scientists, and telecommunication specialists. In addition, a commission, constituting of independent industrial and scientific representatives, oversaw the project's progression and the business relevance of the scientific results.

The work domain and technical support analysis guides developing a theoretical work domain and technical support analysis on three aspects. First, we need to take into account the organizational structure of self-care. Second, we need to study the Human Factors of the different users involved, i.e., patients, medical specialists and technical specialists. Third, we need to map the envisioned technology deployed in the field. The coming sections discuss these three aspects.

2.3.1 *Self-Care Cycle*

During the domain analyses, we gained insights in the ICT requirements of the different users in the health care service. To establish in what context eHealth would be used, Haan and colleagues laid out the main organizational structure of the health care service and mapped out a care plan cycle (Haan et al., 2005)*. As illustrated in Figure 2.2 and listed in Table 2.3, the patient has to perform assessment and intake to enter the care cycle. Based on the intake and the medical dossier, encompassing clinical history, examination findings, diagnosis, treatment, and consent, the patient will receive an opinion about the health status. This will form the base of the care plan set in collaboration with the care giver and performed by the patient. Afterwards, the patient's situation is reexamined and his or her dossier is updated.

The cycle can be entered into a predetermined amount of times, until the patient is declared healed of the symptoms, or continually, for example in case of a chronic disease such as Diabetes Type II. During the cycle, the patient has contact with various medical and technical specialists, such as the general practitioner (GP), internists, nurses, pharmacists, and technical helpdesk. These actors are involved in one or more of the discussed steps, as responsible persons and/or as care executors. For Diabetes type II, specific involved specialists are GP, diabetes nurse, internist, oculist, podotherapist, and service desk for glucose level meter support.

* We want to thank Amy Ahluwalia for her essential contribution to the design of the care cycle.

FIGURE 2.2

Care plan cycle and involved actors, based on study of Amy Ahluwalia at the Leiden University Medical Center.

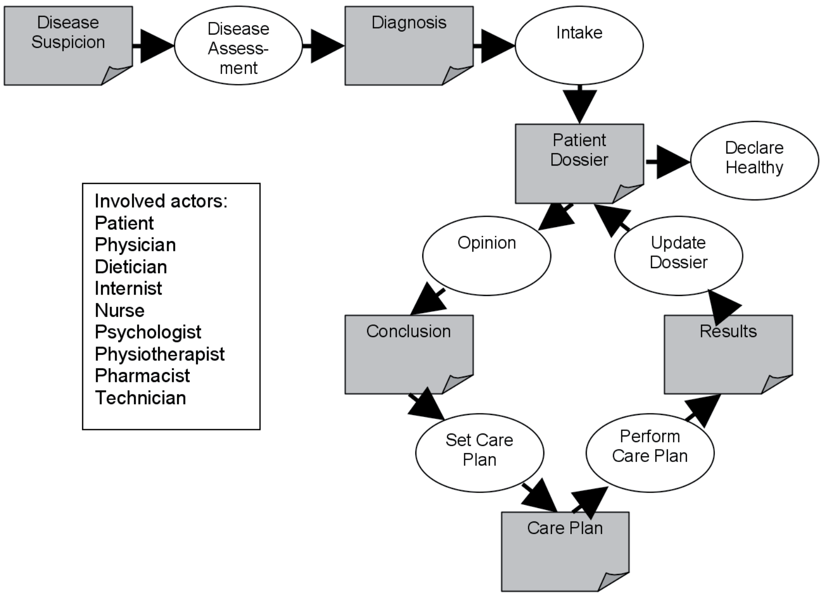


TABLE 2.3

Description of steps in care plan cycle.

Care Plan Step	Description
Disease Assessment	Assessment of patient's syndrome
Intake	Collection/Determination of patient health situation and life style
Opinion	Developing of an opinion regarding the patient's current state as a result of intake or performing care plan
Set Care Plan	Determining care activities performed within a specific timeframe. Activities include education plan, motivation plan, treatment plan (including self-care), consult with third-parties, and appointment for evaluation.
Perform Care Plan	Performing activities determined for the care plan, including maintaining diary of activities.
Update Dossier	Updating of patient dossier based on consult with patient, collected measurement results, care plan results and the advice of third-parties.

For optimal treatment, it is important for the patient to work through the care plan steps and have good communication and information flow with the medical and technical specialists (Schouten, 2004). Daily, the patient has to deal with the trade-offs between maintaining a healthy lifestyle and personal quality of life. To stimulate adherence to the care plan, patient and specialists have to focus on the patient's motivation, health literacy, self-efficacy and goal setting, and adequate use of medical instruments.

2.3.2 *Human Factors*

Personal characteristics play a role in the use and evaluation of eHealth services (Czaja et al., 2006). Namely, personality traits, cognitive abilities, and self-care specific aspects are shown to influence the use and evaluation of technology. First, personality traits influence attitude towards technology and its use. For example, Locus of Control, i.e., the extent to which someone allocates events to internal or external factors, and demographics explain whether people use the Internet for making behavioral decisions about their health care and in which situation. Furthermore, self-efficacy, the Five-Factor Model of Personality, and Need for Closure are factors that explain variance in attitude towards computer use.

TABLE 2.4

Description of personality traits that can influence the evaluation of technology.

Personality traits (Reference)	Description
Locus of Control Scale (Rotter, 1954)	Locus of control refers to a person's belief of the causes of his or her life events and achievements related to health, wealth and social life. People can have an internal locus of control (attributes events and achievements to their own control) or have an external locus of control (attribute events and achievements to external circumstances). An illustrative statement in the Locus of Control Scale is "People must be the master of their own fate."
Five-Factor Model of Personality or Big Five (Thurstone, 1934)	The Big Five personality traits are five broad factors or dimensions of personality. The five factors are: · Openness relates to active imagination, aesthetic sensitivity, attentiveness to inner feelings, preference for variety, and intellectual curiosity; · Conscientiousness relates to acting according to the dictates of one's conscience; · Extraversion relates to being gregarious, assertive, and seeking out excitement and contrasts with introversion, which relates to being reserved, less outgoing, and less sociable. · Agreeableness relates to tendency to be pleasant and accommodating in social situations; · Neuroticism relates to emotional stability.
Need for Closure Scale (Webster & Kruglanski, 1998)	Need for closure describes an individual's desire for a definite answer on some topic in contrast to be amenable to confusion and ambiguity. An illustrative statement in the Need for Closure scale is "Even after I've made up my mind about something, I am always eager to consider a different opinion." The need for closure scale is subdivided in eight aspects, i.e., authoritarianism, intolerance of ambiguity, dogmatism, need for cognition, cognitive complexity, impulsivity, need for structure, and fear of invalidity.

Various researchers have studied the influence of personality traits on eHealth use. Campbell & Nolfi studied computer training for older adults to use the internet to access health care information. The results show that the training did not elicit expected increase in the use of the internet and self-care. Instead, variation was mainly determined by the participants' personal characteristics, including locus of control (Campbell & Nolfi, 2005). Torkzadeh and colleagues examined the contingency model of computer and Internet self-efficacy. They found that, after computer training, people with a positive attitude towards computers and low computer anxiety improved their self-efficacy more than people with a negative attitude. Consequently, this demonstrates the role of attitude and anxiety in computer self-efficacy (Torkzadeh, Chang, & Demirhan, 2006).

Launder & Lounsbury studied the influence of the Five Factor model on internet use (Landers & Lounsbury, 2006). The result of their study showed that internet usage was negatively related to three of the traits: Agreeableness, Conscientiousness, and Extraversion. Thus, when designing websites for users who score low in accommodating to social situations, acting according to their conscience, and assertiveness, it is important to attend to their attitude, i.e., direct special attention to overcome their initial negative attitude towards the internet.

Amichai-Hamburger and colleagues studied the interaction between personality traits and internet technology (Amichai-Hamburger, Fine, & Goldstein, 2004). In their experiment they tested the influence of need for closure and time pressure on the use of interactive and non-interactive websites. Results show that under time pressure, people with a high need for closure preferred the non-interactive website and people with a low need for closure preferred the interactive website. However, without time pressure the effect was the other way round. From this we can defer that different personality characteristics, may influence the evaluation of technology differently, and even contrarily, in different contexts.

Also, cognitive abilities influence technology use. Czaja and colleagues modeled how different cognitive abilities relate to people's use of technology. The authors measured, with the use of formal cognitive abilities tests, the relationship between crystallized intelligence, fluid intelligence, memory, psychomotor, perceptual speed and the use of technology. Their study showed that computer anxiety, fluid intelligence, including spatial ability, and crystallized intelligence, including vocabulary, were important predictors of the use of technology (Czaja et al., 2006). Amongst others, results showed that a decrease of these factors led to lower self-efficacy with respect to use of computers and more computer anxiety.

Especially for older adults, physical and cognitive abilities are of influence (Fisk et al., 2004). Due to the lack of experience with new and innovative technology, older adults tend to use less technology than younger adults. In addition, older adults' experience declines in cognitive abilities, such as short term memory, spatial ability, and processing speed, which can negatively influence their work with computers. As defined in Table 2.5, Carroll distinguished ten cognitive ability aspects of the influence on evaluation of technology (Carroll, 1993).

TABLE 2.5: Description of cognitive abilities that can influence the evaluation of technology (Carroll, 1993).

Cognitive Abilities	Description
Fluid Intelligence	Reason, form concepts and solve problems that often include novel information and procedures.
Quantitative Knowledge	Manipulate numeric symbols and reason procedurally with quantitative information and relations.
Crystallized Intelligence	Communicate about and reason with previous learned procedures
Short-term memory	Hold information in immediate awareness and apply it instantly
Visual perception	Analyze and synthesize verbal stimuli
Auditory perception	Analyze and synthesize auditory stimuli
Long-term retrieval	Store information in long-term memory and to fluently retrieve it later on through association
Decision speed	Speed and accurateness of making decisions and producing answers
Processing speed	Speed of automatic processing, particularity when under pressure
Reading and writing	Read and write native language

Human factor principles can guide the evaluation of eHealth services. Consequently, when aiming at developing technology for various users, human factor principles can drive the design and evaluation process. For example, in his book Usability Engineering, Nielsen listed guidelines for design and evaluation of technology on usability (Nielsen, 1993). He included, consistency, affordances, i.e., quality of an object, or an environment, that facilitates an individual to perform an action, feedback, error messages, standardizing, asking for information and openness about its use, providing manuals, and User-Centered features. Similarly, Norman pointed out seven design principles for usable technology.

These covered providing knowledge about technology, making functions perceivable and interpretable, simplifying task structures, facilitating affordance and mapping, i.e., taking advantages of physical analogies and standards, anticipating for errors and standardization (Norman, 1988).

Fisk and colleagues studied how to design for older adults (Fisk et al., 2004). They focused on perception, cognition and psychomotor and put forward that designers must consider the possible lack of experience with technology, the decrease in visual, auditory, manipulating and cognitive abilities. In accordance, they had a number of recommendations. First, technology has to be consistent with previous representations, expectations and experiences. Second, the interaction should generate visual, auditory and psychometric and cognitive fit by applying support strategies. Examples are breaking up sequences of tasks in smaller subtasks; provide affordance; making the technology adaptable by the user to his or her needs, providing training, and conducting user testing. Moreover, these guidelines are not only handy for older adults but could also be applied to improve the usability of support technology for both generic and specialized complex situations.

2.3.3 *Envisioned Technology*

Research shows that the eHealth services with Personal Computer Assistants could contribute to the issues in the health care domain related to the graying population, shortage of medical staff, managing medical data and need for patient empowerment. Specifically, Multi Agent Systems (MAS) can support patients by searching and modeling key information and presenting it in a personalized manner (Lindenberg, Nagata, & Neerincx, 2003; McLaughlin et al., 2005; Nagata, Oostendorp, & Neerincx, 2004). In addition, it enables distributed human and agent actors to work together and address large-scale real-world problems (Pynadath & Tambe, 2003). Consequently, Chapter 3 discusses, more in depth, the technical feasibility of an eHealth framework with Personal Computer Assistants based on MAS.

2.4 DESIGN SPECIFICATIONS

2.4.1 *Functions and Claims*

In accordance with the Scenario Based Design approach, eHealth should fulfill a number of functions. As listed in table 2.6, following the self-care cycle, the functions are related to retrieving, sharing and managing information, maintaining diary and calendar, communication, and community participation. In practice, these functions are realized through different features. Moreover, the assumption is that they have their positive and negative effects, related to Human Factors, on the use process, experiences and outcomes. These effects need to be made more explicit in the design process in the form of claims (Rosson & Carroll, 2002). Claims point out the trade-offs between the advantages and disadvantages of the determined functions and specific features.

TABLE 2.6

Examples of eHealth functions supporting the self-care cycle and high level claims on their positive and negative outcomes.

Core Functions	Features	Claims
Personalization of information	Creating account, logging in, adjusting medical information to user profile and goals	+ Information is geared to the patient's needs and will increase health literacy – Information is specialized and difficult to recycle for others
Searching and retrieving information	Browsing, referring, printing, accessing (multimodal) overview	+ A broad range of information is accessible to the patient – Difficult for the patient to determine what information is relevant or not which can decrease the efficiency
Sharing information	Sharing information with medical specialists, possibly through the use of an Electronic Patient Record (EPR)	+ Information is accessible for all involved actors, which facilitates common mental model – Security is difficult to guarantee and personal medical data can end in the wrong hands which negatively effects trust
Managing information	Adding and editing personal self-care details in personal database	+ The patient can independently manage medical details which can increase awareness, involvement and self-efficacy – Inexperienced users can erroneously and irrevocably edit medical data which goes at the cost of the patient's safety

TABLE 2.6

Examples of eHealth functions supporting the self-care cycle and high level claims on their positive and negative outcomes (continued).

Core Functions	**Features**	**Claims**
Maintaining calendar and diary	Keep personal self-care details chronically and in relation to daily life with the use of diary	+ Items in the diary can be used to determine behavioral patterns – Patient has to constantly maintain the diary for accurate and consistent overview, which may decrease the satisfaction.
Communication and community participation	Communicating with medical specialists and with peers e.g., through forum	+ Patients can share experience with peers which can help increase self-care motivation – Erroneous information can easily be spread out, which decreases effectiveness

2.4.2 *Scenarios*

Scenarios can play a role in envisioning the set of functions and claims. A scenario is a description that contains actors, background information on the actors and assumptions about their environment, actors' goals or objectives, and sequences of actions and events (Go & Carroll, 2004). Using scenarios as a general representation throughout the entire system lifecycle (analysis, design and prototype & evaluation) is part of Scenario-Based Design.

Rosson and Carroll described two scenario goal levels (Rosson & Carroll, 2002). First, there is a high level goal, which answers the question "who is the story about and why did it take place?" This is represented by the scenario written in Chapter 1: *John (aged 55) suffers from diabetes type II and has to combine his self-care with his daily tasks while maintaining a good quality of life.* Second, there is a low level goal, or subgoal, which describes how the actors reach their goal by using specific technology in a specific context.

Post et al. applied high level goals to facilitate exploration of innovative ICT to support meeting behavior. In their scenario, they described the factors that influence meetings, such as the market, organization, task, team, individual; characteristics, method and tools (Post, Cremers, & Blanson Henkemans, 2004). Respectively, for a design team that has to develop a new remote control, the scenario describes the changing fashion in the market and their company, which faces budget constraints. The team managers, designers, and market experts need to come to an agreement on the remote control functional and conceptual design over different meeting phases with the use of laptops, web browser, and smart boards.

High scenario level goals can support the exploration phase in developing innovative technology, but cannot drive an empirical study. To model and test theoretical assumptions, it is important to shift to lower level goals. For example, in the research of Post et al., the scenarios were further specified in subgoals related to tasks, activities, agenda, and personal goals. Consequently, the researchers could elicit natural meeting behavior in an experimental setting and study the influence of different factors on the meeting on meeting processes and outcomes.

Haan and colleagues applied different scenario goal levels for development of eHealth with Personal Computer Assistants (Haan et al., 2005). They explicitly used the scenarios to support the cognitive engineering approach. After a detailed analysis of the diabetes II domain from a medical point of view, they set functions and developed corresponding scenarios. These were successfully applied to iteratively designing prototypes and testing their practical applicability and usefulness.

In the context of developing eHealth services with Personal Computer Assistants, low level scenario goals correspond with describing how John uses an Online Lifestyle Diary with Computer Assistant to keep track of dietary and physical activities and receive information on how to adhere to his self-care activities in a pleasurable way. *John accesses his Online Lifestyle Diary through internet and logs in. After updating his personal details, including weight and glucose level, he goes to the diet diary page and enters his meals of the day. In addition, he enters his exercise in his activity diary and check marks his medication in the medication page. Then, he looks at the report to see if he has eaten and performed activities in accordance to his care plan. In addition, the diary includes a Personal Computer Assistant, in the form of an avatar, who interacts with the user through text and facial expressions. It monitors his report and informs John on the self-care goals achieved. If certain goals are failed, the assistant expresses why and gives some suggestions on how to perform better next time in accordance to John's daily life.*

In addition, scenarios can be used to stimulate subject involvement. This is especially beneficial when conducting studies in Smart Home Lab settings with healthy participants, who test eHealth services. We will elaborate on this in the next sections. As illustrated in Figure 2.3, the participants receive multi-modal scenarios to help them empathize with the patient situations and encourage them to place the eHealth services in a realistic medical context. In turn, it can help evaluate if eHealth prototypes contribute to achieving their goal, e.g., perform self-care (Kuijten, 2006).

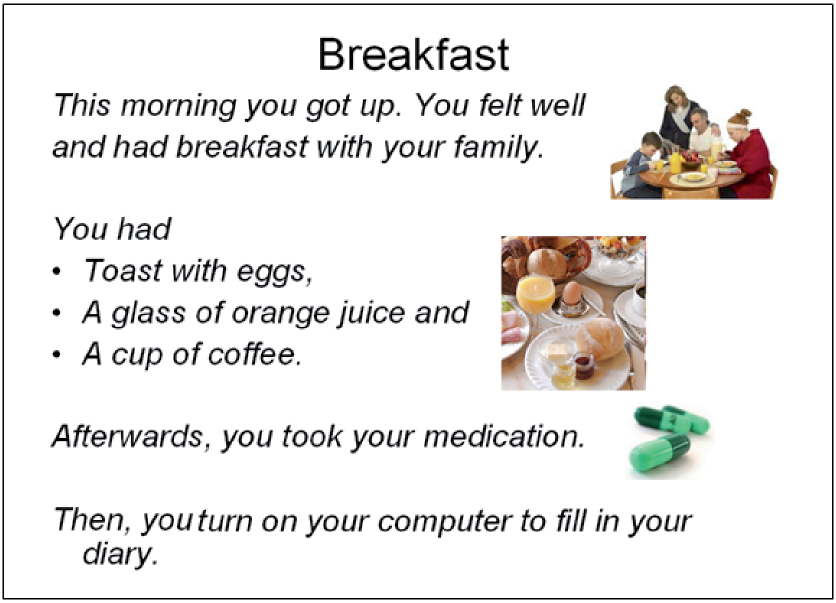


FIGURE 2.3

Example of participant involvement scenario used during Smart Home Lab study to increase empathy with patient situation.

In summary, applying scenarios, at different goal levels, has multiple benefits. They provide shared vocabulary among the system developers and help envision the uncertain future tasks of the system users. Furthermore, they provide a good brainstorming tool for planning and allowed the stakeholders to consider alternatives in decision-making. Finally, they facilitate fleshing out research questions and answering them in experimental setting, by stimulating participants' involvement, eliciting natural behavior and evaluating the influence of innovative technology on the use and outcomes.

2.5 PROTOTYPING AND EVALUATION

Following the CE approach, the design specifications are used for designing and evaluating eHealth prototypes. This produces two problems. First, it is difficult to conduct controlled testing in the actual application environment. Many factors, which are difficult to observe outside the controlled environment, can influence the interaction. Echoed by later studies (Kane, Wobbrock, & Smith, 2008; Streefkerk et al., 2007), Kjeldovski and Stage found challenges in eliciting similar results with both lab studies and field studies (Kjeldskov & Stage, 2004). In their comparison between the two, the authors address differences in measuring usability problems, task performance, and workload.

Second, it is difficult to foresee the, possibly harmful, impact of new technology on the user. For example, in pharmaceutical medical research, drugs go through multiple test phases before the Medical Ethical Testing Commission gives approval for the population's use. Foregoing testing potentially leads to harm to the patient (World Medical Association, 2004). The following sections discuss how we can address these two issues.

2.5.1 *Smart Home Laboratories*

In early stages of the research, studies are preferably conducted in smart home laboratories. Smart Home Labs facilitate testing prototypes by offering a comfortable domestic atmosphere and encourages natural behavior in an experimental setting (Mynatt & Rogers, 2002). Examples of Smart Home Labs, as displayed in Figure 2.4, are the Georgia Tech's Aware Home (www.awarehome.gatach.edu) and TNO/Delft University of Technology's (DUT) Experience Labs (http://www.usabilitytesting.nl).

FIGURE 2.4

Examples of Smart Home Labs: The Georgia Tech Aware Home (left) and the TNO Experience Lab.

Georgia Tech's Aware Home contains functional and design requirements of a normal home, as well as additional sensing and display capabilities to support ubiquitous computing interventions for residents of the house. The Aware Home has a number of advantages over other laboratory environments, including contextualizing technologies under study. Because activities and goals within the home environment differ from those in office environments, traditional usability testing laboratories (which are often designed to look like offices) may be inappropriate (Hindus, 1999). One key difference is that in the home environment a person is free to choose how space and time are structured, what activities are undertaken, and who is involved (Kidd, Orr, Abowd, & Atkeson, 1999). Finally, the Aware Home facilitates the bringing together of researchers from different disciplines, whose disparate knowledge and experience is beneficial in the design of technology.

TNO Human Factors and Delft University of Technology (DUT) both have experience laboratories to accommodate research that samples the experiences of home occupants whose use of technologies and services are still under development. An important focus of both of these laboratories is to develop personalized environments in such a way that a broad range of occupants, including older adults, can easily access the services that might be of interest for them (Neerincx, Lindenberg, & Grootjen, 2005). User, activity, and context profiling technologies are included in the environment to allow the home's system to adapt to the occupant's task performance and well-being. The infrastructure of the laboratories is flexible to enable research with users who move between home and other locations, e.g., office, hospital or gallery, and those who communicate with persons from other locations using personalized information technology, e.g., tele-conference or chat (Lindenberg, Pasman, Kranenborg, Stegeman, & Neerincx, 2007).

2.5.2 *Medical Ethics*

With the design and evaluation of ICT support for the medical domain, medical ethics arise. According to the World Medical Association (WMA) Declaration of Helsinki on ethical principles for medical research involving human participants, "it is the responsibility of researchers in medical research to protect the life, health, privacy, and dignity of the human subject" (World Medical Association, 2004). This can only be achieved by careful assessment of predictable risks and burdens in comparison with foreseeable benefits to the subject or to others. In summary, when conducting research with human participants, but specifically with patients, it is essential to have a distinct balance between the social and scientific benefits and the subject's burdens (Coyle, Doherty, Matthews, & Sharry, 2007). This does not solely apply for testing medication but equally when testing eHealth services.

To assure the benefit and burden balance in evaluating a Personal Computer Assistant with patients, it is important to have an external party review. Independent boards iteratively review the study proposals before conducting the experiments. In the Netherlands, proposals are reviewed internally by the TNO independent commission (TCPE) or externally by the Medical Ethical Testing Commission (METC). In the United States, proposals are reviewed by the Institutional Review Board (IRB). Finally, the findings of the studies need to be made public to increase transparency and allow for public scrutiny. Study results are published in peer reviewed journals and conference proceedings.

To guarantee the wellbeing of the subjects, or more generally, participants, researchers need to assess the candidates' eligibility and provide a clear description of the study. Participants voluntarily comply with the study procedures, are free to end the study at their own discretion, and always have access to an independent medical specialist to whom they can pose questions. Finally, to express their agreement, participants have to sign a waiver of consent. During and after the study, personal data are stored anonymously and managed with care and confidentiality. Moreover, to assess possible patient burdens, we will first conduct studies in Smart Home Labs with healthy participants. Then, we will conduct a randomized controlled trial with patients.

2.5.3 *Designing and Evaluating eHealth Prototypes*

In summary, studies conducted in Smart Home Laboratories can help test eHealth prototypes with Personal Computer Assistants. The rich environment can enable potential users to consider the technologies in context and therefore provide richer input which in turn can be used throughout the design process. Smart home laboratory environments, like Georgia Tech's Aware Home and TNO/DUT's Experience Lab, are important for representative user-centered evaluation of eHealth monitoring technologies. Moreover, the use of scenarios, which describe the applications' functions and claims at different goal levels, can help design and evaluate eHealth prototypes. Mainly, they can help healthy participants empathize with the use of eHealth with Personal Computer Assistants in patient situations. Finally, in later stages of the research, when the benefits and burdens of the evolution process are mapped out, we can conduct studies in the field with actual patients.

2.6 DISCUSSION

In this chapter, we gave an overview of our research methodology. In previous studies, Cognitive Engineering (CE) has proven to be useful for design of innovative technology in complex environments, such as in the space and naval domains. In view of the complexity of the medical domain, we are applying the CE approach for the development of eHealth services for the support of self-care.

Following the CE approach, we conducted a work domain and technical support analysis, covering self-care, Human Factors, and envisioned technology.

First, we analyzed how the patient works through care plan steps and have good communication and information flow with the medical and technical specialists, while maintaining a good quality of life. Second, we studied the effect of Human Factors on the use of eHealth services. They include self-care aspects, demographics, personality traits and cognitive abilities. Moreover, design strategies, e.g., standardization, facilitating mapping and affordance, simplifying tasks, and anticipating errors can help address these factors. Third, we described the benefits of envisioned eHealth services. Specifically, the use of Personal Computer Assistants could contribute to stimulating the use of eHealth.

The analysis was used to set Design Specifications, including functions, claims and scenarios on different goal levels. Iteratively, the Specifications can be used to design and evaluate eHealth prototypes. To address medical ethics, we should conduct studies in Smart Home Labs with healthy participants before conducting studies in the field with patients and have studies reviewed by Medical Ethical Testing Commissions. In turn, the results are used to refine and augment the Design Specifications.

3

FEASIBILITY OF AN eHEALTH FRAMEWORK

Following Chapter 2, which covers the Work Domain and Design Specification, the current chapter discusses the design and qualitative evaluation of an eHealth framework with Personal Computer Assistants (PCA) on technical feasibility. With the use of SuperAssist project's core functions and scenarios, we designed a Digital Diabetes Diary with PCAs, based on a Multi Agent System (MAS). Subsequently, we evaluated whether the framework facilitates multiple distributed agents acting as independent intelligent actors and as Personal Computer Assistants for easy medical data and information management.

Results of our study show that it is technically feasible to develop an eHealth framework with Personal Computer Assistants. Moreover, the Digital Diary with PCA fulfilled our design specifications in relation to personalized support of data management by involved users and agents. In the following chapter, the studied framework will be used for iteratively prototyping and evaluating Personal Computer Assistants for self-care in lab and field settings. This chapter is based on a previously published article.*

* Blanson Henkemans, O.A., Bonacita, S., Cappiello, N., Mast, C.A.P.G. van der, Neerincx, M.A., Pinciroli, F. A Hybrid Multi Agent System Architecture for Distributed Supervision of Chronic Patients in the eHealth Setting. Euromedia 2007, April 25–27, 2007, Delft, the Netherlands.

3.1 INTRODUCTION

As described in Chapter 1, the health care service can benefit from eHealth services. In addition, a framework that combines eHealth with Personal Computer Assistants (PCAS), based on a Multi Agent System (MAS), as proposed in Chapter 2, could improve the self-care process and outcomes. Illustratively, it could support identifying symptoms, generating treatment, and monitoring self-care activities (Haan et al., 2005; Wooldridge, 2004; Zhang & Zhang, 2007). As defined by Maes, agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment and by doing so realize a set of goals or tasks for which they are designed (Maes, 1995). In accordance, Multi Agent Systems (MAS) consist of independent intelligent agents located in the users' environment. Here, they communicate, cooperate and compete with others to achieve individual and collective tasks (Russell & Norvig, 2003). For example, the use of MAS can support diabetes type II self-care by translating mathematical models into identification of medical complications and setting practical glucose regulation. It can support the prescription of treatment, including insulin therapy, diet and physical exercise. Furthermore, the MAS can mediate communication and interaction between the patient, the environment, and other involved actors. In turn, this can improve the relationships between patients and caregivers, detect adverse trends in the patient's health condition proactively, support use of medical instruments, and stimulate patient's motivation and behavioral change. Overall, MAS can support productive and low-cost self-care, information sharing with the involved medical specialists, and enhance the patient's quality of life (Krogt, Bos, & Witteveen, 2002; Lindenberg et al., 2003; Vermeulen, Bohte, Somefun, & Poutré, 2007; Xiao, Shen, Sun, & Cai, 2006). In following these studies on MAS facilitating self-care, the key question of this chapter reads:

Is it technically feasible to develop an eHealth framework with the proposed Personal Computer Assistants?

To answer our research question, this chapter will discuss developing an eHealth framework in accordance with the SuperAssist Design Specifications, as defined in Chapter 2. First, we will work out the Envisioned Technology, whereby we focus on current eHealth services. Second, we discuss the Design Specification, covering the Core Functions and Scenario in detail. Third, we will design a prototype consisting of a Digital Diabetes Diary with Personal Computer Assistants Fourth, we will conduct a qualitative evaluation of the prototype on the functionalities, with the use of self-care scenarios in Smart Home Labs and with healthy younger and older adults. This chapter concludes with the implications of our findings for the technical facility of our framework and its potential use for our subsequent studies.

3.2 CURRENT eHEALTH SERVICES

Currently, there are various projects that conduct research on eHealth technology. For example, the M2DM project developed a multi-access service for the management of diabetes mellitus patients (Larizza et al., 2006). The service consists of a Multi-Access Server with a full range of agents consisting of inexpensive and widely accepted information technologies, such as telephone, personal computers, and glucometers. In addition, it uses web-based technology to enable tele-monitoring, i.e., remote information and knowledge management, and tele-care, i.e., remote consulting and supervision. The agent framework was evaluated over a one year period and results showed that it is technically feasible and accepted by both patients and clinics.

Another example is a study on the use of a Health Buddy System in the Netherlands. The Health Buddy is developed for older patients with chronic diseases who are not experienced with technology (Bigelow et al., 2000). The patients use a simple box with LCD display and four buttons. It enables an automated dialogue, based on the motivational interviewing approach (Miller & Rollnick, 1991), and teaches how to deal with the chronic disease. It sends patients' daily responses, including physiological data, to the medical specialist. In case of a deteriorating condition, the specialist can contact the patient. Study results showed that the patient felt safer, deterioration can be assessed earlier, and it can decrease visits to the clinic (Ramaekers, 2005).

A final example is Philips Motiva, a TV-based interactive healthcare platform. The system uses secure broadband technology to connect patients at home through the television to their care providers. It aims at motivating patients to modify their behavior, to follow their doctor's guidelines, eat right and exercise more. A pilot study with 30 patients with chronic heart disorders showed general acceptance, high level of usability, acknowledgment of relevance, and improved communication. Results were published in 2005 by Royal Philips Electronics (http://www.medical.philips.com/goto/motiva).

These projects apply a centralized or decentralized agent framework approach. As defined in Table 3.1, this implies that the data are collected from the actors in a network, converted to a single format, and stored in one database that serves all its subjects, or that the actors maintain ownership of their data, which then have to be retrieved by other actors. The following section will discuss how these agent frameworks are suitable for the eHealth service with (PCAS) in accordance with the core functions and scenarios set for the SuperAssist project.

3.3 SUPERASSIST FUNCTIONS AND SCENARIO

The Design Specifications, in Chapter 2, lists a number of functions of self-care support through medical information provision. The functions are personalization, searching, retrieving, sharing and managing medical data and information. The main requirements derived from these functions are:

- **The system must include multiple distributed agents that act both as independent intelligent actors in the network and as assistants for the human actors;**
- **It facilitates easy data and information management, including making entries, manipulation and reviewing, by all the involved actors.**

In turn, these functionalities can be illustrated in the following scenario. *John, with diabetes type II, goes for a run. Coming home, he is shaky and sweats profusely. He accesses his Digital Diabetes Diary with a Personal Computer*

Assistant (PCA) on the personal computer and enters his past activity and current symptoms. The assistant assesses an anomaly and summons John to measure his glucose. Subsequently, the PCA receives the glucose value from the glucometer sensor, which confirms a minor hypoglycemic attack. The PCA notifies John of the minor hypoglycemic attack, gives a description of the cause, i.e., glucose level between 4 and 3 mmol/L, and describes the treatment policy, i.e., raise the glucose level. In addition, it provides recommendations on how to execute the treatment in the short term, e.g., drink a glass of sugar water, and long term, e.g., eat sufficiently before exercising in the future. Meanwhile, it notifies the medical specialist's PCA of John's condition. PCA makes a note in John's Electronic Patient Record (EPR). The medical specialist, who is online, receives a notification and contacts John, through a chat service, to discuss his condition.

The earlier mentioned eHealth services offer well-founded agent frameworks that fulfill their project's requirements. However as listed in Table 3.1, these centralized and decentralized agent frameworks also have a number of shortcomings, in terms the SuperAssist Design Specifications mentioned above. To tackle these shortcomings, we developed a hybrid Multi Agent System framework for the support of diabetes patients' self-care. The framework consists of decentralized agents with a central node. The node manages data that the actors want to synchronize, e.g., medical test results and the medical specialists' calendar. It can contain a web server, a communication server and other central systems that need a centralized structure.

TABLE 3.1

Disadvantages of centralized and decentralized agent frameworks.

Centralized agent framework	**Decentralized agent framework**
Constrained flexibility in distributed database management	Difficult to integrate and interoperate different platforms
High dependency on difficultly accessible internal network	Distributed data sources and agents are required to be online for data synchronization
All the computation must take place centrally	Indistinctness of who is managing the data
	Prone to data redundancy

As illustrated in Figure 3.1, agents are working in the background and provide ambient intelligence to the users, who reside in the smart environment. The multiple agents acquire information through sensors, their behavior, and through communication among each other. Examples of information sources are the EPR, Digital Diabetes Diary, and domestic medical instruments, such as a glucometer and blood pressure meter. The patient and medical specialist each have a Personal Computer Assistant (PCA) that acts as mediator for the communication with each other and with the agents (Grill, Khalil Ibrahim, & Kotsis, 2005; Lindenberg et al., 2003).

Based on these functions and scenarios, we will design an eHealth framework with Digital Diabetes Diary and Personal Computer Assistants based on a hybrid Multi Agent System. Consequently, we will qualitatively evaluate if it is technically feasible to develop an eHealth framework with multiple distributed agent. The agents should act both as independent intelligent actors in the network and as assistants for the human actors and facilitate easy data and information management, including making entries, manipulating and reviewing, by all the involved actors.

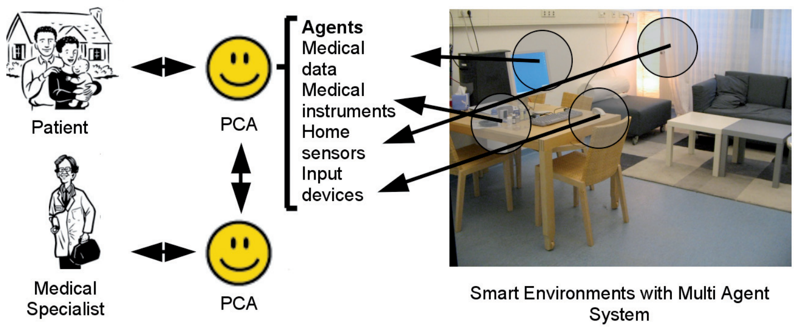


FIGURE 3.1
Multi-Agent System (MAS) working in a smart environment and interacting with the users through their Personal Computer Assistants (PCA).

3.4 DESIGN OF DIGITAL DIABETES DIARY WITH PERSONAL COMPUTER ASSISTANTS

In this eHealth framework, all the data that appear in the Digital Diary are retrieved from the database. The database is initialized with MYSQL and managed by the Java file DatabaseMediator.java and the library agendaDb.db. The Unified Modeling Language (UML) case diagram represents the tasks performed by the actors within the system to communicate with the database. These tasks are divided in four objects, namely storing data (agendaDb.util), presenting the graphical user interface (agendaDb.GUI), implementing the agents (agendaDb.agent), and verifying that the user is in the database (agendaDb.agenda) before initiating the interaction (TestMessage).

3.4.1 *Agent Communication and Database*

To enable optimal functionality, different agents run simultaneously on the patient and medical specialist's computers and communicate with each other. As illustrated in the use case, which specifies the course of events between the user and the system (Jacobson, Christersson, Johnsson, & Overgaard, 1992), in Table 3.2, we have implemented two agents using the JADE platform. These are the PatientAgent on the patient's computer and the NurseAgent on the medical specialist's computer. Both agents are communicating with the user's diary (Agenda), which contains nutrition, activities, and health condition. The agent communication takes place by sending messages reciprocally. To recognize the different kind of messages, the behavior of the agent changes according to the prefix of the message. For example, if the message starts with "start" the chat becomes active and if it starts with "chat" the chat window will show the message sent by the medical specialist. The third type of prefix is "response" followed by the name of the measurement, e.g., blood pressure. Also, the PatientAgent checks how the new measurements influence the status of the patient.

TABLE 3.2: Example of use case and Java code in the event of a minor hypoglycemic attack.

Use Case	**Java Code**

Agenda:
Glucose level is between 3 and 4 mmol/L
	public int statusHypo()
	{
	double level=this.glucoseLevel;
	if((3<=level)&&(level<4)) return 1;
	if(level<3) return 2;
	else return 0;
	}

PatientAgent:
Glucose level indicates a minor hypoglycemic attack, assistant sets policy and provides recommendations
	if(diary.statusGlucoseLevel()==1)
	{
	String newMotive=”GlucoseLevel: “+diary.getGlucoseLevel();
	med.changeStatus(myPatient,1,myPatient.getStatusMotive()
	+newMotive);
	myPatientGui.hourAgent=hour;
	myPatientGui.ResetPersonalComputerAssistant();
	if(diary.statusHypo()==1)
	myPatientGui.addHypoQuestions();
	else
	myPatientGui.addHyperQuestions();
	myPatientGui.Refresh();
	}

NurseAgent:
Nurse contacts patient through chat service
	if(msg.getContent().startsWith(“start”))
	{
	System.out.println(“trying to chat”);
	myNurse.StaRCThat();
	}
	if(msg.getContent().startsWith(“chat”))
	{
	myNurse.ReceivedMessage(msg.getContent().substring(6));
	}
	try
	{
	Thread.sleep(30000);
	}
	catch (InterruptedException e)
	{
	e.printStackTrace();
	}
	ACLMessage reply = msg.createReply();
	reply.setPerformative(ACLMessage.INFORM);
	reply.setContent(response+ myNurse.getMeasure());
	send(reply);
	}

3.4.2 *Personal Computer Assistant Activities*

The Personal Computer Assistants enable the involved human actors to interact with the different agents in the environment. This is realized through the performance of three main activities: managing data, formulating policies and making recommendations.

The medical specialist enters and updates patient data, e.g., demographics data, medical history, and clinical diabetes information. The patient keeps track of self-managing tasks in a personal Digital Diabetes Diary, including current mood, exercises performed, meals consumed, medication taken, and blood glucose level measured. The patient and the medical specialist enter data in the database through the Patient and Nurse Interface, respectively. Also, they can enter data in collaboration with their Personal Computer Assistants (PCAs). For example, when the Assistant detected a minor hypoglycemic attack, it can note this in the diary. Based on the data in the Digital Diabetes Diary and Electronic Patient Record, the patient's PCA gives short-term recommendations and long-term policies. For example, it can recommend drinking a glass of sugar water or eat starch and, as policy suggests, prevention of hypoglycemic attacks can occur by balancing exercise and food intake. In our experiment setting, the PCA bases its prescribed recommendation and policies predominantly on the results of the glucose test results, due to its importance in diabetes care (Houweling, Kleefstra, Verhoeven, Ballegooie, & Bilo, 2004). Finally, the Assistant makes recommendations on how these policies should be executed.

The connection of the PCAs with the database is established through a Java Database Connectivity (JDBC) platform and the Application Program Interface (API). The latter is a programming interface allowing external access to the database for manipulation and update commands. Also, it allows the integration of SQL calls into a general programming environment by providing library routines, which interfaces with the database. In theory, all actors have their database, which is synchronized with a central node. In our experimental setting, we designed the framework so that the database, containing the Electronic Patient Record and the Digital Diabetes Diary, is located on the patient's side. Thus, when the patient is online, the database and current patient data are accessible by the medical specialist. When the patient is offline, the medical specialist has access to the patient's data retrieved the last time the patient was online and the databases were synchronized.

3.4.3 *User Interfaces*

Both the patient and medical specialist have an interface with a Personal Computer Assistant. This section will shortly discuss the interfaces. The patient's interface consists of six fields (Figure 3.4):

1 A Digital Diabetes Diary in which the patient logs the performed self-care tasks;
2 Access to the Electronic Patient Record (EPR);
3 Entering medical test results and viewing old medical results;
4 A "traffic light" indicating current health status based on diary and last measurement results (green: healthy, orange: be aware, red: alert!);
5 A chat service to communicate with the remote medical specialist;
6 A frame to communicate with the Personal Computer Assistant.

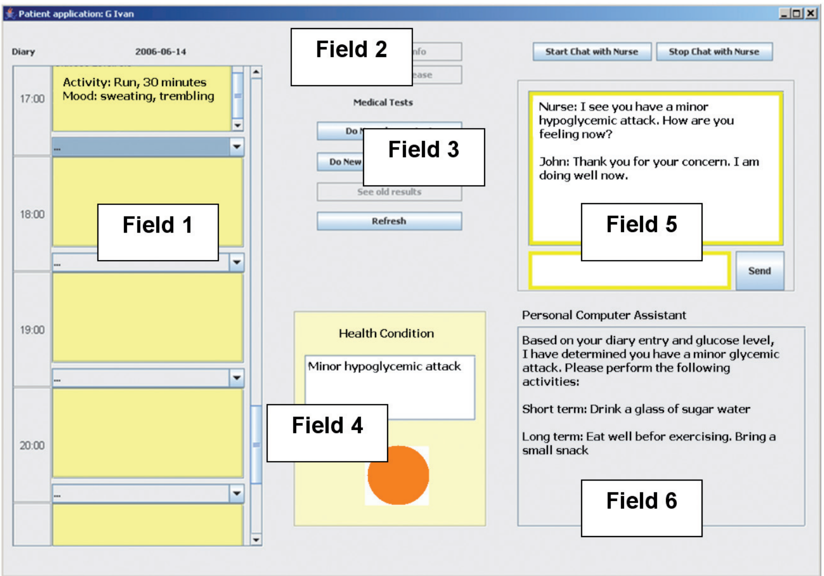


FIGURE 3.2

Patient Interface, containing 1. Digital Diabetes Diary, 2. EPD access, 3. Retrieving tests results, 4. Traffic light, 5. Chat service, and 6. Personal Computer Assistant communication frame

The medical specialist also has an interface for remote monitoring of the patients. This interface can be divided in three main fields (Figure 3.5):

1 **List of the patients in the medical specialist's folder with the current health status represented by the accompanying traffic light. Clicking on the patient will provide a screen more in-depth information;**
2 **Access to Patient Data Management;**
3 **A chat service to communicate with the patient.**

FIGURE 3.3

Nurse Interface, containing 1. Patient List, 2. Access to Patient Data, and 3. Chat service.

As modeled in the UML case diagram (Figure 3.3), the data from the Digital Diary are accessed by the PatientAgent and NurseAgent through the message moderator (TestMessage). The two agents interact with the users through the interface represented by GUI.Patient and GUI.Nurse. In addition, the Patient-Agent can access the results of the medical test results entered by the patient through the glucose and blood pressure interface (GUI.GlucoseLevel and GUI. BloodPressure). Finally, the Utility package (util.Patient) contains the data that are stored in or retrieved from the Electronic Patient Record. The package contains glucose level and blood pressure thresholds for the measurements to enable the agent to determine the patient's health condition. Consequently, the

PatientAgent sets the policy, which signals an accompanying traffic light and, in turn, directs the Personal Computer Assistant's recommendations.

3.5 EVALUATION OF DIGITAL DIABETES DIARY WITH PERSONAL COMPUTER ASSISTANTS

Our goal was to qualitatively evaluate whether the proposed hybrid eHealth service with Personal Computer Assistant, based on a Multi Agent System (MAS), is technically feasible. Consequently, in accordance with the SuperAssist project's core functions and scenarios, we will test if the framework facilitates multiple distributed agents acting as independent intelligent actors and as Personal Computer Assistants for easy medical data and information management.

As listed in table 3.3, nine students and two older adults, evaluated the framework, respectively, at Delft University of Technology (DUT) and TNO's Experience Labs with the use of participants involvement scenario. This is in accordance with the approach discussed in Chapter 2 where Smart Home Labs can facilitate testing prototypes of new technologies by offering a comfortable domestic atmosphere and encourage natural behavior in an experimental setting, while contextualizing the experience. Moreover, the participants, who were healthy, worked with the Digital Diary with PCA according to predefined scenarios to help them empathize with and play the role of a patient and place the system in context.

TABLE 3.3
Overview of participants in qualitative experiment (N=11).

Younger adults			
Total	Male	Female	Mean age (SD)
9	4	5	25.34 (5.5)
Older adults			
Total	Male	Female	Mean age (SD)
2	1	1	70.5 (12.0)

During the experiment, we observed the subject remotely with both an overview camera and a close-up camera. The setup is illustrated in Figure 3.4. We had access to the medical specialist interface and a clone of the patient's interface. Furthermore, we logged the communication between the two agents. The observations provided a good overview of the tasks performed by the subject, the communication between the agents, and the functionality of the two Personal Computer Assistants. Finally, the participants completed surveys on their opinion on the patient PCA's usability.

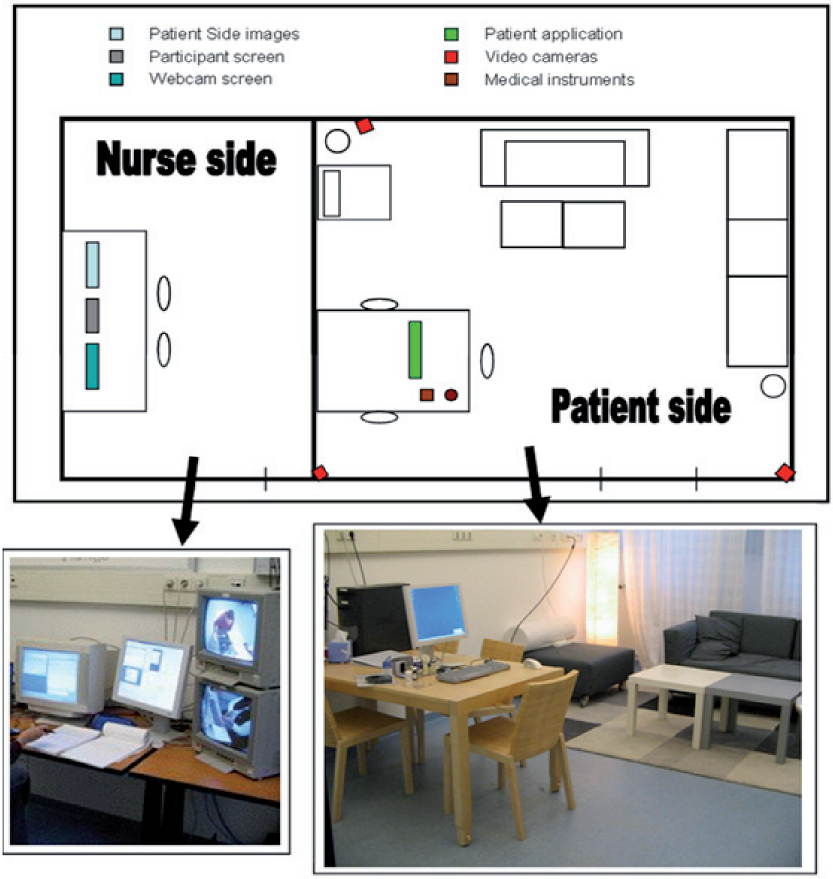


FIGURE 3.4

TNO Experience Lab

3.6 RESULTS

In regard to the analysis, we studied two functionalities. First, we studied if we could deploy multiple distributed agents that could act both as independent intelligent actors in the network that manage the data and as assistants for the involved human actors. Second, we studied if the system with Digital Diabetes Diary facilitates easy data management by all actors.

Concerning deploying multiple distributed agents, we were able to develop two separate artifacts, i.e., the patient system and the nurse system, which could be coupled step by step. When both PCAs were online, they could correctly add and retrieve data to and from the database, containing the Electronic Patient Record (EPR) and the Digital Diabetes Diary. In the case of a health critical situation or when the patient sent a message to the medical specialist, the two PCAs could communicate with each other directly. In practice, the patient logged self-care tasks in the Digital Diary and, based on the data, the patient's PCA made inferences about the patient's health status and gave feedback. The new data, based on the interaction between the patient and its PCA, was then sent to the database and retrievable by the medical specialist's PCA.

Concerning easy data and information management by the involved actors, we observed that the data were accessible and manageable. The patient and the Personal Computer Assistant could edit the Digital Diabetes Diary and view the EPR. The medical specialist could add new patients to the database, edit the EPR, and view the patient's Diabetes Diary and current health status. The medical specialist's PCA could view the patient Digital Diabetes Diary, EPR and current health status. When the patient's PCA was offline, it could still comment on the diary entry and subsequently add the new data to the database. When the patient's PCA was online again, the medical specialist's PCA could synchronize the new data. The patient's PCA reacted accurately and quickly to the newly added data of the patient Digital Diary independent of the type of task or the health situation of the patient. The data were correctly added to the database and retrieved by the medical specialist's PCA. Also, the communication between the two PCAs was instantaneous. Concerning the usability of the system, according to the usability survey, on a scale of 1 through 7 (7 being very usable) participants rated the usability of the assistant, on average, a 6.54 (*SD*=0.52). The younger adults rated the usability, on average, a 6.55 (*SD*=0.52) and the older adults rated the usability, on average, a 6.50 (*SD*=0.71).

3.7 DISCUSSION

The results of our qualitative evaluation show that it is technically feasible to develop an eHealth framework prototype according to the proposed SuperAssist Design Specifications. Based on analysis of current eHealth services and the project's functionalities and scenarios, we designed and qualitatively evaluated a Digital Diabetes Diary with personal Computer Assistant to support self-care. The prototype covers interaction of distributed actors, both human and agents, tools, e.g., glucometer, and data sources, e.g., Electronic Patient Records and Digital Diabetes Diary. Also, it facilitated support for diverse health situations of the user, such as hypo- and hyperglycemic attacks. The evaluation took place with younger and older adults in a Smart Home Lab setting.

The results depict that the developed hybrid Multi Agent System (MAS) framework meets with the functions and scenarios. The framework, consisting of decentralized agents with a central node, facilitated multiple distributed agents that act both as independent intelligent actors in the network and as assistants for the human actors. Also, it facilitated easy data and information management, including making entries, manipulation and reviewing, by all the involved actors. These functionalities work adequately and are comprehensible by both younger and older adult users through a usable Personal Computer Assistant.

Although the eHealth framework generally fulfilled our Design Specifications, the evaluation showed that the system needs refinement and augmenting on multiple aspects. One aspect that needs to be refined is the agents' intelligence and awareness of processes. Currently, the Personal Computer Assistants only monitor newly added data and do not consider the dynamics over time. For example, with diabetes patients, but also with other chronic diseases, such as asthma, the course of their health is as important as their current health state. This could be solved by looking at existing data and deploy pattern recognition (Kushniruk & Borycki, 2008). Another aspect is the necessity to elaborate on privacy and security issues, such as risks of corporate espionage, consumer/personal privacy validation, and location privacy (Xiao et al., 2006). If we want to deploy the framework in real practice, we will have to further study the problems and restrictions these issues pose. Finally, we suggest augmenting the system by adding a technical specialist to the framework. The technical specialist, also equipped with a Personal Computer Assistant, could help maintain and troubleshoot technical problems with both the system itself and the domestic medical instruments used by the patient.

These results and implications contribute to the SuperAssist project's aim to address the current issues in the health care domain and study how eHealth services can alleviate them. On the one hand, we based our framework on the Work Domain and Technical Support Analysis, which cover the self-care theories, Human Factors and current eHealth services. On the other hand, the framework enables integrating Personal Computer Assistants in eHealth, evaluating user experience, finally, refining and augmenting our Design Specifications. Consequently, we can apply the proposed framework for the study on Personal Computer Assistants for self-care.

In conclusion, it is technically feasible to develop an eHealth framework with Personal Computer Assistants based on a Multi Agent System. Also, we expect that with the use of the Cognitive Engineering approach, the framework facilitates further refining and augmenting of the Design Specifications. As a result, it could be applicable for the support of self-care of chronic patients in the eHealth setting. In the next part, we will discuss studies conducted in Smart Home Labs and field settings with eHealth prototypes based on the framework discussed in this chapter.

4

TROUBLESHOOTING OF DOMESTIC MEDICAL INSTRUMENTS

As medical instruments are used more-and-more at home, a patient's maintenance and troubleshooting of such instruments is becoming an important issue in self-care. To address this issue, we designed a Troubleshooting Environment with Personal Computer Assistant that provided different feedback styles for domestic medical instruments. The Environment consisted of a frame with the display of the medical instrument and a frame for the user-Computer Assistant interaction. We evaluated two feedback styles in a smart home lab setting with younger adults using scenarios that focused on the medical instrument's maintenance and troubleshooting: a cooperative condition, which aims at user participation and interaction, and, a directive condition, which aims at relieving the user of its tasks. Also, we evaluated a baseline condition, in which the participants used the standard user manual.

The results show that the Computer Assistant improves maintenance and troubleshooting of domestic medical instruments. Moreover, the cooperative feedback was more effective and satisfying, whereas the directive feedback was more efficient. Finally, personal characteristics, i.e., computer experience, education level, spatial ability, reading skills, reading speed, locus of control, and fear of invalidity, explained variance in troubleshooting process and outcomes. Future design of Computer Assistants must contain different feedback styles to facilitate personalized support of troubleshooting of domestic medical instruments. This chapter is based on a previously published article.*

* Blanson Henkemans, O.A., Neerincx, M.A., Lindenberg, J., Mast, C.A.P.G van der. SuperAssist: A User-Assistant Collaborative Environment for the supervision of medical instrument use at home. 1st International Conference on Pervasive Computing Technologies for Healthcare 2006, November 29-December 1, 2006, Innsbruck, Austria.

4.1 **INTRODUCTION**

One aspect of patient self-care is the use of domestic medical instruments for monitoring the current health condition. For example, diabetes patients commonly use instruments to measure glucose, blood pressure and heart rate. The use of these instruments is strongly dependent on good functioning. For example, *John monitors his meals, exercise and glucose level. Based on the data, he can maintain a stable and healthy glucose level. For John it is important to assess the correct glucose level, otherwise his self-care activities may be counteractive. Consequently, he has to perform maintenance regularly and to troubleshoot, i.e., detect and solve, technical problems that may occur with the instrument.*

Like John, many patients use domestic medical instruments and are confronted with the complex task to maintain and troubleshoot them independently (McLaughlin et al., 2005).

4.1.1 *Maintenance*

Maintenance aims to eliminate system failure traps and hazards to ensure that equipment continuously works within designed tolerances and specifications (Cooney, 2001). Moreover, it ensures that the defined functions and standards of operations of equipment are capable of being performed for the required period (Ashayeri, Teelen, & Selen, 1996). Maintenance tasks are complex due to low frequency of occurrence, operating manuals with a high information density, and the importance of handling precision. In addition, it requires distributed attention; one must keep an eye on the manual, the instrument's failure symptoms, and its own actions.

4.1.2 *Troubleshooting*

Troubleshooting consists of a search for likely causes of faults through a potentially erroneous problem space of possible causes (Schaafstal et al., 2000). Also, the different cognitive abilities such as reasoning capacities, application of knowledge, and application of sensors of human physiological measures play an essential role in the success of the troubleshooting activities (Carroll, 1993; Fischer, 2001). Existing conceptualizations of troubleshooting (Axton, Doverspike, Park, & Barrett, 1997; Johnson, Ferej, Flesher & Jehng, 1996; Jonassen, Howland, Moore, & Marra, 2003; Perez, 1991; Rasmussen, 1984) can be integrated in four subprocesses:

1 **Representing the problem (assessing discrepancies between the system's current state and ideal state);**
2 **Diagnosis or fault isolation, including remembering previous experiences, exploring the problem space, generating hypotheses, gathering information (observing and testing components), hypothesis evaluation and decision making;**
3 **Selecting, implementing and evaluating solution options, and;**
4 **Adding experience to personal experience library.**

In an optimal situation, the subprocesses are run through once, but it is likely that a troubleshooter has to repeat a subprocess or go one or more subprocesses back before the failure is detected and tackled.

4.1.3 *Personal Computer Assistant*

One of the benefits of eHealth is supporting the use of domestic medical instruments (Rogers et al., 2007). In addition, the use of a Personal Computer Assistant can contribute to fitting the support to the users' capabilities, which are related to maintenance and troubleshooting. These capabilities concern background knowledge, objectives, cognitive capacity, and context. In addition, the use of personal Computer Assistants enables distributed human and agent actors to work together and address large-scale real-world problems (Hoc, Cacciabue, Hollnagel, & Norton, 1996; Lindenberg et al., 2003; Maguire, 2001; Neerincx et al., 2006; Payne et al., 2000; Pynadath & Tambe, 2003)

Research showed that different feedback styles influence user performance and satisfaction (Lindenberg et al., 2003). Feedback influences the way people will interpret, accept and, apply information given by the assistant. For example, it can disrupt the user's current activity, but can also help a user understand better why certain actions have to take place. As illustrated in Figure 4.1, to support patients using medical instruments at home, we designed a Troubleshooting Environment to interact with the Personal Computer Assistant, and the key question of this chapter reads:

How can a Personal Computer Assistant, applying cooperative and directive feedback style in text and images, support maintaining and troubleshooting of domestic medical instruments?

To answer our question, this chapter discusses the design of the Trouble-

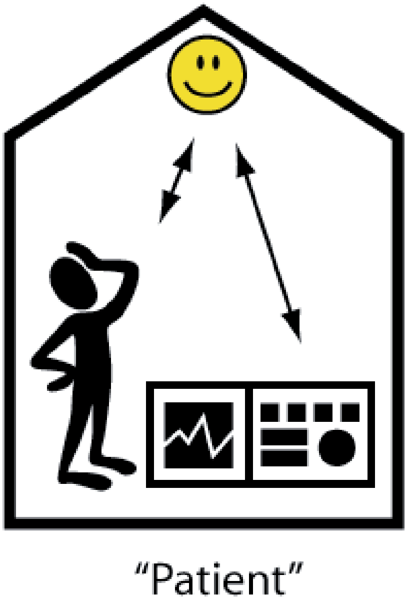


FIGURE 4.1

Personal Computer Assistant for maintaining and troubleshooting of domestic medical instruments.

shooting Environment with Personal Computer Assistant and the evaluation of different feedback styles on maintenance and troubleshooting in a Smart Home Setting, i.e., the TNO Experience Lab. The current environment is a first concept and we aim at assessing the influence of the feedback styles on maintenance and troubleshooting and want to minimize variation in personal characteristics. Consequently, the participants' pool will consist of a homogenous student group and they evaluated the feedback styles according to scenarios. In the following experiments (see next chapters), we will evaluate Personal Computer

Assistants with participants who have specific characteristics of the target user group and can benefit from the Troubleshooting environment (Anne Collins McLaughlin et al., 2005), such as older adults and overweight people.

4.2 TROUBLESHOOTING ENVIRONMENT WITH PERSONAL COMPUTER ASSISTANT

4.2.1 *User Interface*

As illustrated in Figure 4.2, we developed a Troubleshooting Environment application that facilitates interaction with the Personal Computer Assistant to maintain and troubleshoot domestic medical instruments. The program runs on a Laptop and, during our study, supports the use of a DCA 2000+ HbA1c analyzer*. Bayer manufactured the analyzer to measure Hemoglobin A1c, the average glucose level of the patient over the previous three months. It is currently used by the general practitioners and medical laboratories, but it is likely that in the near future cheaper and more simplified versions, which are suitable for use at home, are brought on the market. Moreover, we want to stress that the majority of the problems presented to the participants was fictitious and do not match real-life experiences with the Bayer DCA 2000+ analyzer.

The application's interface contains three frames. It contains a top frame which instructs the participants in relation to their tasks. This was mainly to direct the experimental process. Also, it contains a frame with replicas of the DCA 2000+ LCD display and buttons. This was used by the participants instead of the original DCA 2000+ analyzer interface. Consequently, the different sources, i.e., textual and graphical computer assistance and the DCA 2000+ display, offer the information required for maintenance and troubleshooting within one frame. Physical manipulation of the instrument, such as replacing parts, does take place on the DCA 2000+. Finally, it contained a frame presenting the textual and graphical feedback of the Computer Assistant.

* For further details www.ascensia.ch/pub/fr/produits/dca2000.asp (viewed May 2009).

FIGURE 4.2

Operating the DCA 2000+ analyzer (light gray) at home with the Troubleshooting Environment (on laptop).

4.2.2 *Cooperative and Directive Feedback*

During the study, the participants used the Troubleshooting Environment program to interact with the DCA 2000+ and the Personal Computer Assistant (PCA). Following the theory on the contribution of Computer Assistants and feedback on technology use, we applied three feedback conditions (see Table 1.3, section 1.4.3):

- **Cooperative feedback style: The Assistant focuses on user participation and interaction, suggests possible actions, and guides the user step by step through maintenance and problem-solving processes;**
- **Directive feedback style: The Assistant works individually and relieves the user of its tasks within its capacity. Ideally it independently performs diagnosis and compensatory actions and afterwards reports the actions to the user;**
- **Baseline Condition: Instead of interacting with the Assistant, the users receive a paper manual with instruction.**

To control the information context between the Baseline and Personal Computer Assistant (Cooperative and Directive), text and figures were literally taken from the original operation manual. No information was added and the layout remained the same.

As illustrated in Figure 4.3, an example of a troubleshooting task was to perform a "SET UP" and to verify if the instrument functioned properly. During the set up, a failure arose and the application displayed error code "E3" on the LCD display. In the Baseline condition, the Troubleshooting Environment refers to the official instrument operating manual at hand. The cooperative assistant facilitates diagnosis of the problem through question and answer and guides the user through the relevant compensatory steps of action. The directive assistant independently performs diagnosis and performs compensatory action. It only reports the performed actions afterwards. If actions outside the directive assistant's ability are required, e.g. physical manipulation, the user receives updates and instructions. In the example case, the diagnosis was that the program card contacts were dirty and the instrument couldn't complete "SET UP". The compensatory action was to clean the program card's contacts with an eraser and place it back in the instrument.

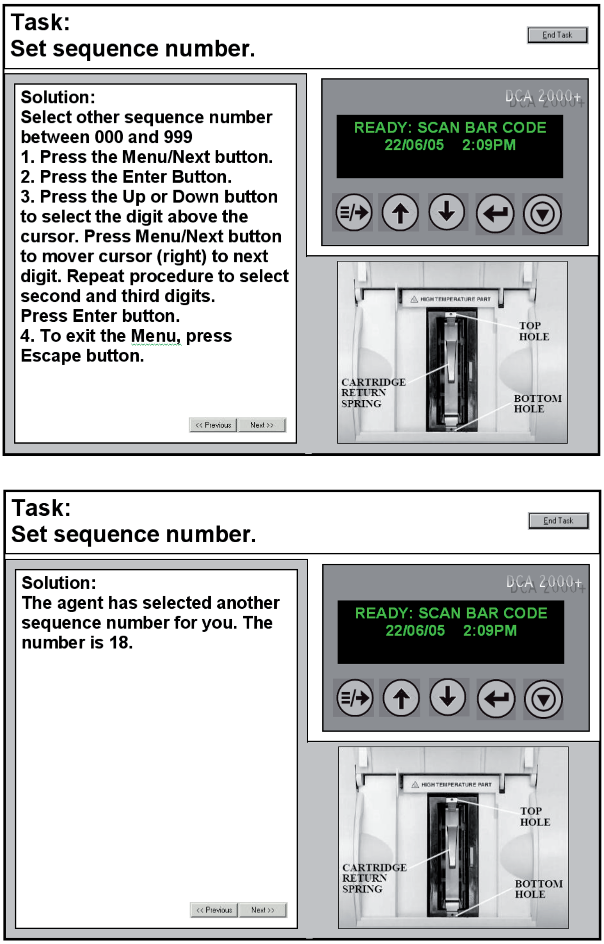


FIGURE 4.3

Interface of Troubleshooting Environment the cooperative (above) and directive assistant. Text is translated from Dutch to English and enlarged for readability.

For this study, we designed a Troubleshooting Environment with Personal Computer Assistant, which provides cooperative and directive types of feedback, for maintenance and troubleshooting of domestic medical instruments. The feedback of the Computer Assistant is driven by a Wizard of Oz setup, which implies that the experiment leader remotely, in accordance with a prescribe template, sends messages to the participant. Consequently, we will evaluate if a Personal Computer Assistant applying different feedback styles can support maintaining and troubleshooting of domestic medical instruments in an effective, efficient and satisfying way. Although we aimed at creating a homogeneous participant group, we nevertheless anticipate some differences in cognitive abilities and personality traits. Thus, we will analyze their explanatory value of personal characteristics concerning the variance in use of the Troubleshooting Environment and its outcomes.

In accordance with the literature, we expect that, the assistant will enable better performance and will be more preferred in comparison with no assistant (McLaughlin et al., 2005). In regard to the different feedback styles, we expect that the cooperative feedback will lead to a more effective and satisfying performance and the directive feedback will lead to more efficient performance (Bass, 1960; Nagata et al., 2004). Also, we expect that users react differently to complex technical tasks. People apply different strategies when confronted with technical failures due to dissimilarity in experience of assessing problems, generating hypotheses based on former experience, and the knowledge of possible compensatory actions. It is likely that the participants' characteristics related to these strategies, i.e., demographics, cognitive abilities and personality, will influence the effect of the assistant feedback on the use of the application and its outcomes (Carroll, 1993).

4.3 METHOD

The participants' pool consisted of 26 younger adults. Three additional experiment runs served as a pilot and were used to optimize the Troubleshooting Environment and validate the cases. These results are not considered in the sampling. As listed in Table 4.1, the final group consisted of 12 male and 14 female bachelor's (vocational education) and master's (academic education) students, aged between 18 and 36 (*M*= 22.42, *SD*=3.43).

	Male	**Female**	**Total**
Bachelor	6	8	14
Master	6	6	12
Total	12	14	26

TABLE 4.1

Frequency table of male and female bachelor's and master's students (*N*=26).

The participant performed cases according to operating scenarios. In accordance with the scenario, the participants empathized with a patient working with a medical instrument at home. The participants maintained and troubleshot a DCA 2000+ HbA1c analyzer.

Participants performed nine cases in one of the three conditions according to a between subject design. They had to perform three maintenance cases, e.g., cleaning the instrument, and six cases in which the participants had to solve technical failures, e.g., replacing a blown fuse. Each participant completed the tasks with one feedback style or the baseline condition. After completing the nine cases, the participants repeated one case in the two remaining conditions and rated them on preference. Because the Computer Assistant is not fully operational, we applied the Wizard of Oz method (Kelley & Thomas, 1983). In accordance with a preset template, the experiment leader directed the interaction between the Computer Assistant and the participant.

During the experiment, we measured two aspects of personal computer assistance. The first aspect is maintenance and troubleshooting. Specifically, the goal is to assess if the environment with Computer Assistant providing different feedback styles contributes to maintenance and troubleshooting. The second aspect is the influence of personal characteristics on the evaluation of the environment and the Computer Assistant feedback. To determine the effect of the Computer Assistant on maintenance and troubleshooting medical instruments, we measured the troubleshooting outcomes, concerning:

1 **Effectiveness: Number of cases the participants solved;**
2 **Efficiency: The accuracy of the troubleshooting and maintenance steps in comparison with the ideal operation manual, total performance time, and indication of experienced effort on a Rating Scale Mental Effort (RSME) (Zijlstra, 1993);**
3 **Satisfaction: Participants' preference for condition.**

To determine whether personal characteristics influenced the above-mentioned usability factors, participants completed a survey on biographic data, education level, and computer experience; a number of human cognitive abilities (Fischer, 2001), i.e., reading skill and speed (based on timed high school exam English reading test), and spatial ability; Locus of Control, which indicates the extent to which one believes that reinforcements and rewards are a function of one's own behavior (internal locus) or a function of chance, fate, powerful others, etc. (external locus) (Rotter, 1954); Personal Fear of Invalidity (PFI) that indicates individual differences in the fear of making judgmental errors (Thompson, Naccarato, Parker, & Moskowitz, 2001).

To analyze the effect of the Computer Assistant on the Troubleshooting Environment's effectiveness and efficiency, we did an independent t-test by groups. To analyze satisfaction, we did a Chi-square analysis on the participants' preference. Finally, to explain the variance in usability evaluation by personal characteristics, we did a regression analysis with 7 predictors. These were age, education level, spatial ability, reading skill, reading speed, Locus of Control, and Personal Fear of Invalidity.

4.4 **RESULTS**

In regard to effectiveness, as displayed in Figure 4.4, participants with the Computer Assistant completed more cases successfully (*M*=7.61, *SD*=1.33) than without Computer Assistant (*M*=4.63, *SD*=1.40), $t(24)=5.18$, $p<.001$. Moreover, participants receiving cooperative feedback completed more cases (*M*=8.22, *SD*=0.83) than when receiving directive feedback (*M*=7.00, *SD*=1.50), $t(16)=2.14$, $p<.05$.

Considering efficiency, participants with Computer Assistant performed the troubleshooting and maintenance steps more in line with the instructions (*M*=4.11, *SD*=2.30) than participants without (*M*=6.75, *SD*=3.24), $t(24)=2.38$, $p<.05$. Furthermore, as illustrated in Figure 4.5, participants with Computer Assistant performed the cases in less time, in seconds, (*M*=2490.56, *SD*=635.02) than participants without (*M*=4567.50, *SD*=2166.52), $t(24)=3.80$, $p<.001$. Moreover, participant receiving directive feedback performed their cases quicker, in seconds, (*M*=2178.89, *SD*=558.49) than participants receiving cooperative feedback (*M*=2802.22, *SD*=571.35), $t(16)=2.34$, $p<.05$. In relation to performing cases versus with solving cases, we want to remark that we measured the time participants needed to perform all 9 cases, independently if they solved it or not. Moreover, to prevent excessive time use, when participants were irreversibly stuck in a case, we indicated that they could continue to the next case. Finally, on a scale of 35 (low level of experienced effort) to 107 (high level of experienced effort), participants with Computer Assistant scored on average 57.85 (*SD*=16.14)

FIGURE 4.4

Cases solved in the Baseline Condition and with the Computer Assistant, t(24)=5.18, p<.001, providing Cooperative or Directive Feedback, t(16)=2.14, p<.05.

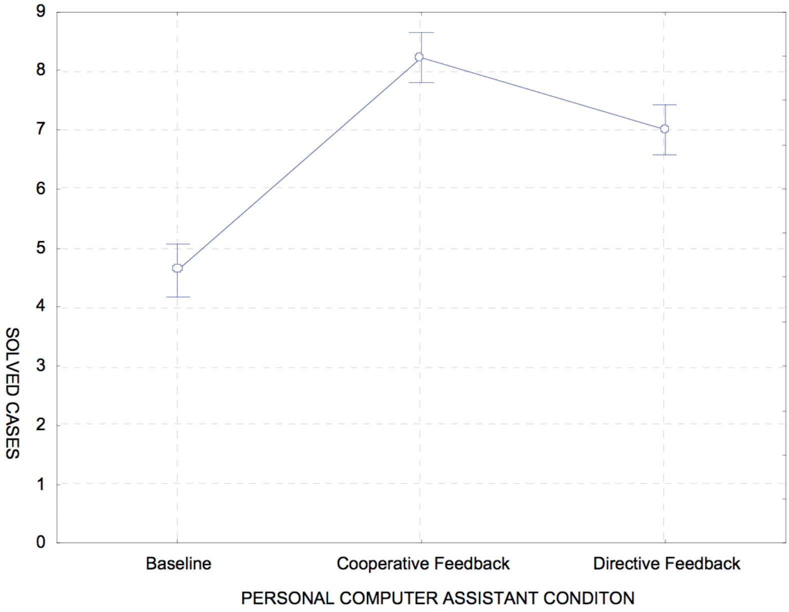
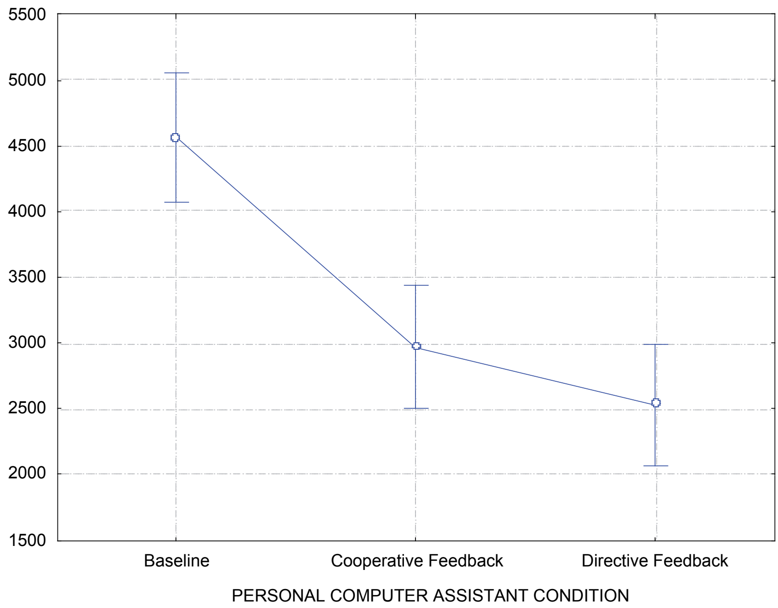


FIGURE 4.5

Time used to perform 9 cases in the Baseline Condition and with the Computer Assistant, t(24)=3.80, p<.001, providing Cooperative or Directive Feedback, t(16)=2.34, p<.05.



and without 68.50 (*SD*=25.32), t(24)=1,30, p=0.21. There was no significant effect of the assistant feedback style on and the accuracy of the troubleshooting and maintenance steps and the effort experienced.

As listed in Table 4.2, participants had the highest preference for the Computer Assistant providing cooperative feedback and the lowest preference for baseline condition. From the 26 participants, 17 indicated that their first preference (Pref1) was for to the cooperative assistant, 8 preferred the directive assistant and only one participant expressed the highest preference for the baseline condition. Moreover, 18 rated the baseline condition as least preferred (Pref3), 6 participants indicated they preferred the directive feedback the least, and only 2 participants preferred the cooperative feedback the least.

	Baseline	**Cooperative Feedback**	**Directive Feedback**
Pref1[1]	1	17	8
Pref2[2]	7	7	12
Pref3[3]	18	2	6

[1] $\chi^2(2)$=14,85, p<.001
[2] $\chi^2(2)$=1,92, p=.38
[3] $\chi^2(2)$=16,00, p<.001

TABLE 4.2

χ^2 test statistics on highest (Pref1), middle (Pref2), and lowest (Pref3) preference for assistant condition, with an expected value of 8.67.

Multiple regression analysis showed that personal characteristics explained variance in the evaluation of the Troubleshooting Environment. As listed in Table 4.3 and in line with previous research (Carroll, 1993; Czaja et al., 2006), cognitive abilities and personality traits explained variance in usability. This consists of effectiveness, i.e., the number cases participants solved, efficiency, i.e., the average effort they experienced, the accuracy of the troubleshooting and maintenance steps in accordance with the instruction made, and the average time they needed while performing the nine cases, and satisfaction, i.e., the preference they had for condition.

TABLE 4.3

Multiple regression analysis of Troubleshooting Environment's usability.

Variable	Explained variance by predictor variables	R^2 (%)	Regression equation
Cases solved	Spatial ability (SPAT)	20	Solved = 0.15 + 0.25*SPAT + 0.36*RSK – 0.30*FI + 0.20*RSP
	Reading Skill (RSK)	7	
	Fear of Invalidity (FI)	6	
	Reading Speed (RSP)	4	
	Total	37	
Experienced Effort to perform the cases	Computer Experience (CE)	16	Effort = 55.40 – 0.30*CE – 0.51*FI + 0.41*RSP + 0.28*LOC + 0.24*RSK
	Fear of Invalidity (FI)	16	
	Reading Speed (RSP)	9	
	Locus of Control (LOC)	7	
	Reading Skill (RSK)	4	
	Total	52	
Accuracy of steps	Education Level (EL)	44	Accuracy = -1.33 + 0.40*EL + 0.43*RSK + 0.29*RSP – 0.23*FI
	Reading Skill (RSK)	10	
	Reading Speed (RSP)	6	
	Fear of Invalidity (FI)	5	
	Total	65	
Time used to perform cases	Reading Speed (RSP)	31	Time = -1108.35 +0.64*RSP + 0.20*LOC
	Locus of Control (LOC)	3	
	Total	34	
Preference for directive feedback style	Computer Experience (CE)	18	Preference = 2.09 – 0.45*CE + 0.49*LOC + 0.44*RSP – 0.21*FI – 0.22*EL
	Locus of Control (LOC)	12	
	Reading Speed (RSP)	8	
	Fear of Invalidity (FI)	5	
	Education Level (EL)	4	
	Total	**47**	

4.5 DISCUSSION

Today's patients are using multiple medical instruments at home. Maintenance and troubleshooting strongly determine if the use is safe and measurements are accurate. Consequently, we designed a Troubleshooting Environment with

Personal Computer Assistant for domestic medical instruments. To study how a Personal Computer Assistant can support maintenance and troubleshooting of domestic medical instruments, we conducted an experiment at the TNO Experience Lab with younger adults.

Results showed that participants working in the Troubleshooting Environment with Personal Computer Assistant were able to perform maintenance and solve technical problems. In contrast, the baseline condition, which resembles the conventional process where users consult a paper operating manual, proved relatively impractical. Concerning the influence of different feedback styles, the cooperative feedback elicited the most effective performance and was considered the most preferred. Directive feedback elicited the most time efficient performance. This is in line with existing theory (Bass, 1960).

Personal characteristics explained variance in the different aspects of the Troubleshooting Environment's usability. First, participant with higher scores for spatial ability, reading skill and reading speed, and Fear of Invalidity, solved more technical problems. Second, participants who scored lower on readings skill and speed and computer experience, scored higher on Fear of Invalidity, and had an internal Locus of Control, experienced more effort when performing the cases. Third, participants who scored lower on education level, reading skill and speed, and Fear of Invalidity, diverted more often from the instructions in their cases. Fourth, participants who scored lower on reading speed and had predominantly an internal Locus of Control, required more time to perform the cases. Finally, participants with a low score on computer experience, reading speed, education level, but with a high score for Fear of Invalidity, and an internal Locus of Control, had a higher preference for the directive Computer Assistant. Although the cooperative Assistant proved most effective and most preferred, personal characteristics explained variance in experienced effort, diversions from troubleshooting instructions, and preference for Computer Assistant feedback style. Accordingly, when aiming for a usable Troubleshooting Environment, in addition to looking at the Computer Assistant feedback style, one should incorporate requirements based on personal characteristics, i.e., cognitive abilities and personality traits.

This chapter discusses a first experiment, with healthy younger adults, and provides a good starting point for further development. In Chapter 5, we will design and evaluate a new version of the Troubleshooting Environment with three additions. First, the user has the possibility to add experiences to a personal experience library. This gives them the opportunity to look back on their experience and more easily react to similar technical problems in the future. Second, we will test it with older participants. Older adults, who experience the most difficulties with the use of medical instruments at home, could specifically benefit from this system. Finally, we will test if the Troubleshooting Environment could support communication with a technical specialist in case that the patient can not solve technical problems solely in collaboration with the assistant.

In conclusion, a Troubleshooting Environment with a Personal Computer Assistant can contribute to patient's maintenance and troubleshooting of domestic medical instruments. Additionally, receiving cooperative feedback – which focuses on user participation and interaction, suggests possible actions, and guides the user step by step through maintenance and problem-solving processes – leads to the most effective performance and was declared most preferred. On the other hand, the user receiving directive feedback, implying that the assistant works individually and relieves the user of tasks within the Assistant's capacity, leads to the most effective performance. Furthermore, choice of assistant can be explained by personal characteristics, in particular computer experience, education level and fear of invalidity. Consequently, assessing them beforehand could be of help to tune the Computer Assistant feedback style to the user.

5

REMOTE COLLABORATIVE TROUBLESHOOTING OF DOMESTIC MEDICAL INSTRUMENTS

Personal Computer Assistants can support troubleshooting of domestic medical instruments. However, failure can be of such gravity that the help of a Technical Specialist is necessary. Due to differences in personal characteristics, e.g., age and level of expertise, this can be considered challenging for the patient. To support remote collaborative troubleshooting, we redesigned the Troubleshooting Environment with Personal Computer Assistance discussed in Chapter 4. We evaluated the influence of cooperative and directive feedback on remote collaborative troubleshooting in smart home lab setting with younger and older adults. The older adults played the role of a novice patient using medical instruments at home and the younger adults played the role of a remote expert technical specialist. The participants remotely collaborated according to troubleshooting scenarios which aimed at emphasizing with their roles.

Results showed that collaboration is optimal when older patients receive cooperative feedback and technical specialists receiving directive feedback. Moreover, personal characteristics (i.e., age, computer experience, education level, spatial ability, and locus of control), explain variance in the troubleshooting process and outcomes. This chapter is based on a previously published article.*

* Blanson Henkemans, O.A., Neerincx, M.A., Sawirjo, V.M., Mast, C.A.P.G. van der, and Lindenberg, J. A Computer Assistant for Remote Collaborative Troubleshooting of Domestic Medical Instruments. 2nd International Conference on Pervasive Computing Technologies for Healthcare 2008, January 29-February 1, 2008, Tampere, Finland.

5.1 INTRODUCTION

Chapter 4 discussed the design of a Troubleshooting Environment with Personal Computer Assistant for domestic medical instruments. Results showed that the use of a Personal Computer Assistant can support patients performing maintenance and troubleshooting technical failures independently at home. However, in some cases, the failure is of such gravity that the help of a Technical Specialist is necessary.

John experiences a complex technical problem with his glucose meter, which cannot be resolved solely with the support of his Personal Computer Assistant. Consequently, he calls the help desk that remotely supports him with the troubleshooting process. John, as an older adult and novice user, faces challenges when communicating on the phone with a younger technical specialist. For example, John experiences difficulties communicating the state of the medical instrument and its failure. In addition, he rarely fully understands the steps the specialist wants him to perform.

Like John, many patients face challenges to solve usage problems with domestic medical instruments. Especially older adults are faced with this challenge. They are more prone to chronic diseases, such as diabetes type II, which require the use of medical instruments for self-monitoring, such as a glucometer, and are less experienced with innovative technology. Strikingly, medical instruments are generally described as easy to use, previous research has proven the opposite (Rogers, Mykityshyn, Campbell, & Fisk, 2001).Thus, they are dependent on these instruments to make educated choices in their self-care (Mykityshyn, Fisk, & Rogers, 2002), but have greater chance to experience problems with troubleshooting technical failures. Finally, as illustrated in the scenario, even with the remote support of a technical specialist, it can be hard to solve a usage problem.

5.1.1 *Remote Collaborative Troubleshooting*

The findings in the previous chapter showed that a Personal Computer Assistant can improve the troubleshooting of medical instruments by a patient at home. However, to address the issue described in the scenario, we need to augment our initial setting and add a technical specialist for remote collaborative troubleshooting of domestic medical instruments. Figure 5.1 illustrates how multiple Personal Computer Assistants can support the different actors involved by monitoring the use of domestic medical instruments and mediating the communication.

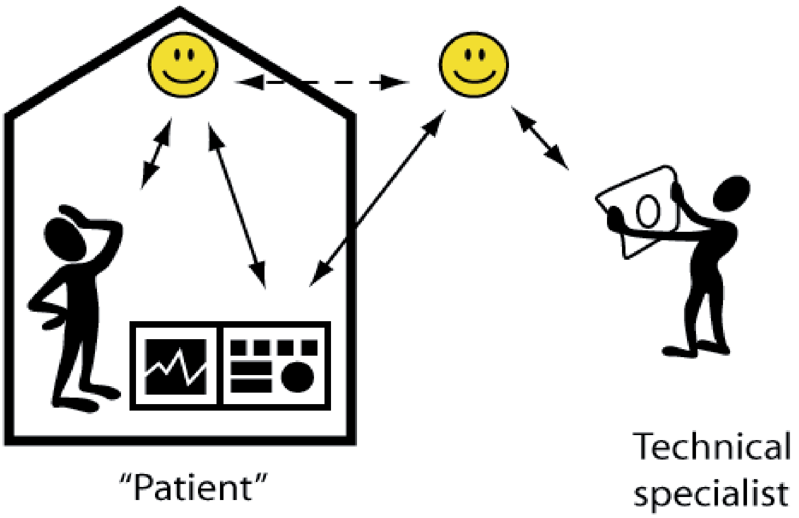


FIGURE 5.1

Personal Computer Assistants supporting patient and remote technical specialist collaboratively troubleshooting medical instrument at home.

As described, this remote collaborative troubleshooting poses a new challenge. The technical specialist is an expert in the domain and often is younger then the clients who need support. This creates a discrepancy in experience and congestive abilities.

5.1.2 *Personal Computer Assistants*

In the previous chapter, the Personal Computer Assistant (PCA) showed that the cooperative assistant was more effective and satisfactory, whereas the directive assistant was more efficient. Cooperative feedback, has a coaching character, explains and educates, and expects high participation of the users. Directive feedback has an instructing character with brief reporting and expects low participation of the user. Furthermore, personal characteristics, i.e., cognitive abilities and personality traits, proved to have a moderating effect on how people evaluated the Troubleshooting Environment with Computer Assistant. However, in the new scenario, the patient and technical specialist each have a PCA that detects failures and provides assistance to solve the problem through feedback and demonstration. In addition, the PCAs mediate the communication between the patient and technical specialist, by offering relevant information of user, usage and context.

The Computer Assistant for remote collaborative troubleshooting has two specifications. First, it should support troubleshooting, which is defined as a search for likely causes of faults through a potentially erroneous problem space of possible causes (Schaafstal et al., 2000). Second, it should support remote collaboration between older novice patients in their home environment and younger technical specialists in their professional environment (Dourish, 2006). The latter implies it should provide relevant information and accommodate feedback to different users with different types of personal characteristics, e.g., age, expertise and cognitive abilities. Consequently, in this chapter our key question reads:

> *How can Personal Computer Assistants, applying cooperative and directive feedback styles in text and images, support remote collaborative troubleshooting of domestic medical instruments?*

To answer our question, this chapter discusses the design of a Collaborative Remote Troubleshooting Environment with Personal Computer Assistants. Moreover it discusses the evaluation of different feedback styles on remote collaborative troubleshooting. This takes place in a Smart Home Lab setting, i.e., the TNO Experience Lab, with older adults, playing the role of patient, and younger adults, playing the role of technical specialist, performing activities according to scenarios. As discussed in Chapter 2, a benefit of this Smart Home Environment is the opportunity to facilitate natural behavior in a controlled environment.

5.2 COLLABORATIVE REMOTE TROUBLESHOOTING ENVIRONMENT WITH PERSONAL COMPUTER ASSISTANTS

5.2.1 *User Interfaces*

As illustrated in Figure 5.2, the Computer Assistants monitor, interact with and mediate the communication between the patient and the technical specialist. This takes place through patient's and technical specialist's Collaborative Troubleshooting Environment Interfaces. Both interfaces consist of an assistant feedback window and chat service, which facilitates communication between the patient and technical specialist. In addition, the Patient Interface displays the interface of the medical instrument currently in use.

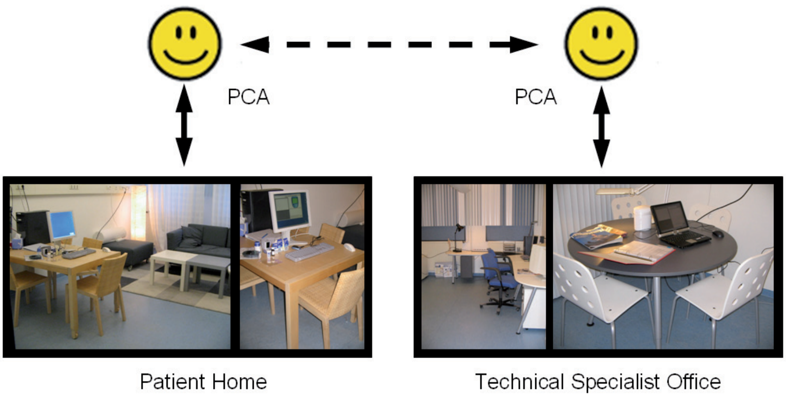


FIGURE 5.2

Personal Computer Assistants (PCA) interact with and mediate the communication between the patient and the technical specialist.

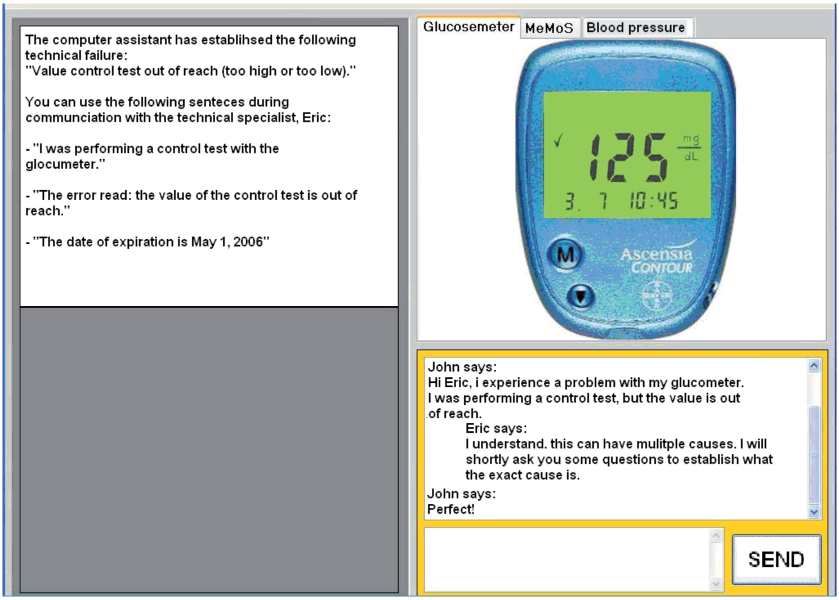


Figure 5.3

Patient Interface with Personal Computer Assistant support with cooperative feedback style, medical instrument interface, and chat service. Text is translated from Dutch.

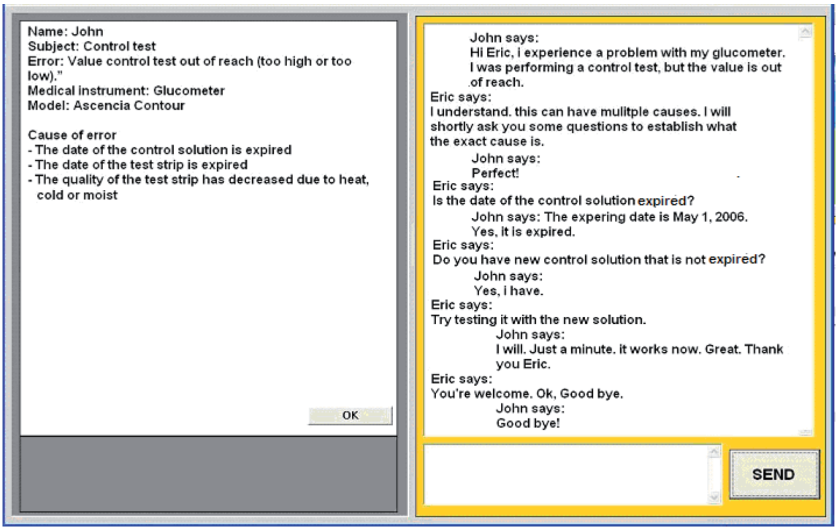


Figure 5.4

Technical Specialist Interface with Personal Computer Assistant support with directive feedback style and chat service. Text is translated from Dutch.

As described in Table 5.1, the patient's assistant (PPCA) monitors the medical instruments, i.e., glucometer, blood pressure meter and digital pill box. In case of a malfunction, it notifies the technical specialist's assistant (TSPCA). The assistants mediate the communication between patient and technical specialist.

The mediation follows the general conceptualization of troubleshooting (Jonassen et al., 2003), which, as described more elaborately in Chapter 4, consists of representing the problem (assessing discrepancies between the system's current state and ideal state); diagnosis or fault isolation, including exploring the problem space, generating hypotheses, gathering information, hypothesis evaluation and decision making; selecting, implementing and evaluating solution options; adding experience to knowledge database. To generate feedback, the assistants' knowledge and reasoning is based on the medical instruments' operation manual. The manual serves as reference for the assistant, concerning the possible errors, cause, and solution.

TABLE 5.1

Activities of patient, technical specialist and Computer Assistants during troubleshooting process

Patient(P)	**P Computer Assistant(PPCA)**	**TS Computer Assistant(TSPCA)**	**Technical Specialist(TS)**
	Define problem field		
Observe current instrument state; Establish problem	Monitor medical instrument technical data; Establish problem; Send overview to P & TSPCA	Receive overview problem from TSPCA; Present problem to TS	Receive overview problem
	Diagnosis		
Receive diagnosis from PPCA	Receive diagnosis from TSPCA; Present diagnosis to P	Provide relevant data from knowledge database to TS; Receive diagnosis from TS; Send diagnosis to PPCA	Start diagnosis process; Receive relevant data from knowledge database from TSPCA; Send diagnosis to TSPCA
	Perform compensatory actions		
Receive compensatory actions from PPCA; Manipulate instrument	Receive compensatory actions from TSPCA; Present compensatory actions to P Check success of compensatory action	Provide relevant data from knowledge database to TS; Receive compensatory actions from TS; Send compensatory actions to PPCA	Start repair process; Receive relevant data from TSPCA; Establish compensatory actions; Send compensatory actions to TSPCA
	Store comments to knowledge database		
Add comments to knowledge database	Add process knowledge database	Add process knowledge database	Add comments to knowledge database

5.2.2 *Cooperative and Directive Feedback*

Following Chapter 4, the assistant can provide two types of feedback styles. The cooperative feedback supports the patient by involving the user in the diagnosis process, explaining step by step the failure and cause, suggesting compensatory actions, and indicating how these problems can be prevented. The directive feedback supports the user by stating the autonomously assessed failure and cause, and instructing the compensatory actions. To illustrate the different feedback styles of the Computer Assistants, Table 5.2 shows the Computer Assistant feedback of the patient and technical specialist receiving cooperative and directive feedback. In the example, they try to collaboratively solve a technical failure related to an unproportionally high or low glucose test result.

Table 5.2

Examples of Cooperative and Directive feedback styles for the patient and technical specialists.

	Cooperative	**Directive**
Patient making contact and defining problem field	Contact with the Technical Specialist is established. While executing the control test, you have received the following error: Control test value out of reach (too high or low). During the chat session, you can use the following sentences: “Date of first use control solution and test strip: May 1, 2006.” “I was doing a control test with the glucometer” “I received an error message saying that the test value is out of reach”	Contact with the Technical Specialist is established. Date of first use, control solution and test strip: May 1, 2006.
Technical Specialist diagnosing problem and suggesting compensatory actions	Contact with the Patient is established. Cause of received error: The date of expiration of the control solution after first use has passed (31% relevance) The date of expiration of the test strip after first use has passed (29% relevance) The quality of the test strip has decreased due to exposure to heat, cold or fluid (22% relevance) The control solution is not at room temperature (18% relevance)	Contact with the Patient t is established. Cause of received error: The date of expiration of the control solution after first use has passed (31% relevance) The date of expiration of the test strip after first use has passed (29% relevance) The quality of the test strip has decreased due to exposure to heat, cold or fluid (22% relevance) The control solution is not at room temperature (18% relevance)

Table 5.2

Examples of Cooperative and Directive feedback styles for the patient and technical specialists (continued).

Cooperative	Directive
Press Next to start diagnose steps. Next: Is the date of expiry of the control solution passed? Yes/No Yes: The patient should not use the control solution with passed expiration date. Repeat the control test with a new control solution. Press Next for instructions on how to perform a control test. No: Is the date of expiry of the test strips passed? Yes/No Yes: The patient should not use test strips with passed expiration date. Repeat the control test with a new control solution. Press Next for instructions on how to perform a control test. No: Is the quality of the test strip decreased due to exposure to heat, cold, or fluids? Yes/No Yes: The patient should not use test strips that are exposed to heat, cold, or fluids. Press Next for instructions on how to perform a control test. No: Is the control solution at room temperature? Yes/No Yes: The control test solution needs to be at room temperature. The patient needs to repeat the control test with a solution at room temperature. Press Next for instructions on how to perform a control test.	The following instructions are chosen to resolve the problem. Press Next and read the instructions. Press OK to send the instructions to the patient. OK: Diagnose: The quality of the test strip has decreased due to exposure to heat, cold or fluids. The patient should not use test strips that are exposed to heat, cold, or fluids. Press Next for instructions on how to perform a control test.

To study the influence of the different feedback styles, we will evaluate if Personal Computer Assistants applying different feedback styles can support remote collaborative troubleshooting of domestic medical instruments in an effective, efficient and satisfying way. From our earlier findings, we formed two assumptions. First, a cooperative feedback style is oriented towards user satisfaction and long-term development and the directive dialogue mode is oriented towards quick and efficient problem solving in cases of anomalies. Consequently, we expect the best team performance for a patient receiving cooperative and a technical specialist receiving directive feedback. Second, in line with previous research described in section 2.3.2 (Czaja et al., 2006; Campbell & Nolfi, 2005), we expect that personal characteristics will moderate how the users evaluated the Troubleshooting Environment with Assistant. Mainly, we expect that age, education level, computer experience, spatial ability and locus of control will effect the use of the proposed technology.

5.3 METHOD

The participants' pool consisted of two groups of each 16 adults, which were categorized as younger and older. The younger adults were aged between 19 and 35 (*M*=22, *SD*=2.68) and the older adults were aged between 42 and 80 (*M*=59, *SD*=10.56). The younger adults consisted of eight males and females. The older adults consisted of ten males and six females. Participants received a small incentive for their participation in this study which lasted 3 hours.
In the preparation of the study, participants completed a number of surveys. First, participants completed surveys on demographics and computer experience and were tested on spatial ability. Second, they were tested on their level of internal or external locus of control (LOC) (Rotter 1954).

During the study, in accordance with a within subject design, an older adult and a younger adult performed four similar scenarios: a scenario where they respectively play the role of patient and technical specialist who both received cooperative feedback; a scenario where they both received directive feedback; a scenario where the patient received cooperative and the technical specialist received directive feedback; a scenario where the patient received directive and the technical specialist received cooperative feedback. To control transfer effects, the feedback conditions were counter-balanced across the four scenarios.

Participants collaboratively troubleshot medical instrument failures remotely through their interfaces, according to four scenarios. The scenarios represent every day use of the medical instruments and possible failures that can occur. The older adults had to work with medical instruments. Examples of malfunctions are low battery, a stuck lever, and an erroneously placed pill. Participants did not have prior knowledge about these medical instruments, but the technical specialists were instructed to study the operation manuals for a fixed time at the beginning of the experiment.

During the experiment, we observed the influence of the assistants' feedback styles on the troubleshooting process and outcomes, concerning effectiveness, efficiency, and satisfaction. Effectiveness was measured by the number of technical failures that were solved. Efficiency was measured by logging the time required to solve a failure and mental effort experienced. Mental effort concerns the resources required to perform the task and was measured using the RSME (Zijlstra, 1993). After every scenario, participants indicated on a scale ranging from 35 (no effort) to 107 (extreme effort), how much effort they experienced. Afterwards, to evaluate the satisfaction, participants were asked to express their preference for one of the two feedback styles (i.e., cooperative or directive).

To evaluate the Computer Assistant feedback usability, we calculated the z-score (to compare performances on tasks according to four similar but not identical scenarios) and conducted a repeated measure ANOVA. In regard to the objective variables effectives and time, we compared the different combination of feedback styles for each team. Mainly, we wanted to look specifically at the synergy of different feedback style combinations in relation to team outcome, i.e., we anticipate that the effect of two feedback styles combined is greater than the sum of the two individual team members. Furthermore, the outcomes of these measures for the two team members within one team were equal, e.g., if a technical problem was solved; this was the case for both patient and technical specialist. In regard to the subjective measure effort, which was different for team members within in one team and relates more to the individual experience and not to the team outcome, we compared the effort of the different individuals. To assess if participants had a preference for feedback style, we performed a χ^2-test. To determine whether there was a relationship between personal characteristics and evaluation of the assistant's usability, we conducted multiple regression analyses on the participants' performance data with 5 predictors, i.e., age, education level, computer experience, spatial ability, and locus of control.

5.4 RESULTS

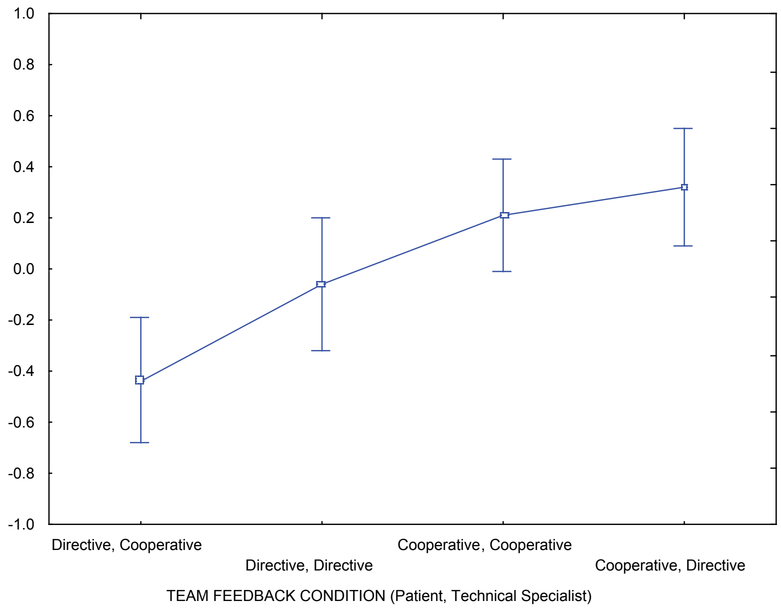
Results show that feedback type influences effectiveness. Figure 5.5 shows the means and standard error of the different feedback style combinations. Teams consisting of a patient receiving cooperative and technical specialist receiving directive feedback solved significantly more technical failures (*M*=.32, *SD*=.92) than the teams consisting of a patient receiving directive and a technical specialist receiving cooperative feedback (*M*=-.43, *SD*=.99), $F(1,15)=2.09$, $p<.05$.

Concerning efficiency, we studied the time required and effort experienced while solving technical malfunctions. Results did not show significant influence of different feedback combination on the time, which teams required. Overall, results did show that patients significantly experienced more effort (*M*=.45, *SD*=.24) than technical specialists (*M*=-.42, *SD*=.22), $F(1,15)=14.76$, $p<.05$.

To evaluate the subject's satisfaction with the feedback styles, we surveyed their preference. Of the older adults, 11 of the 16 participants (69%) indicated they preferred the cooperative feedback style, $\chi^2(1)=4.50$, $p<.05$. The younger adults' preference was bisect.

FIGURE 5.5

Effectiveness of Personal Computer Assistant for collaborative troubleshooting measured as function of malfunctions solved (z-score) by patient and technical specialist teams receiving cooperative and directive feedback combinations, F(1,15)=2.09, p<.05.



Results showed that personal characteristics moderated the evaluation of the Computer Assistant. Table 5.3 and 5.4 list the factors that accounted for the variance in the evaluation by the patient and technical specialist, respectively, of the assistant's usability, concerning effectiveness (i.e., cases solved), efficiency (i.e., time required to perform cases and effort experienced while performing cases), and satisfaction (i.e., preference for feedback style).

TABLE 5.3

Multiple regression analysis of Troubleshooting Environment's usability for patient's personal characteristics.

Variable	Explained variance by predictor variables	R^2 (%)	Regression equation
Cases solved	Locus of Control (LOC) Spatial Ability (SPAT) Computer Experience (CE)	17 9 9	Cases = -27.02 + 0.63*LOC + 0.55*SPAT + 0.39*CE
	Total	25	
Time needed to perform cases	Age Education level (EL) Spatial Ability (SPAT)	54 6 3	Effort = -7.83 – 0.68*Age + 0.22*EL – 0.24*SPAT
	Total	63	
Preference for Cooperative Feedback style	Spatial Ability (SPAT) Age Education level (EL) Locus of Control (LOC)	24 19 15 4	Preference = -12.44 + 1.44*SPAT + 0.80*Age + 0.39*EL + 0.23*LOC
	Total	62	

TABLE 5.4

Multiple regression analysis of Troubleshooting Environment's usability for technical specialist's personal characteristics.

Variable	Explained variance by predictor variables	R^2 (%)	Regression equation
Effort experienced while performing cases	Education Level (EL)	21	Effort = 73.95 – 0.45*EL
	Total	21	
Preference for Feedback style	Locus of Control (LOC)	24	Preference = -1.11 + 0.49*LOC
	Total	24	

5.5 DISCUSSION

In this chapter, we evaluated a Troubleshooting Environment Personal Computer Assistant that supports remote collaborative troubleshooting of domestic medical instruments. The patient and technical specialists each had an assistant that monitors their environment and provides feedback, either cooperative or directive, according to the generally conceptualized troubleshooting process. Additionally, the Computer Assistants mediated the communication by offering relevant contextual information.

Teams consisting of a patient receiving cooperative feedback and a technical specialist receiving directive feedback were the most effective. Overall, during the different cases, patients experienced more effort than technical specialists. Concerning satisfaction, older adults preferred the cooperative feedback style. In addition, other personal characteristics influenced the evaluation of the feedback styles. Illustratively, older adults with a higher internal locus of control, better spatial ability and computer experience tended to solve more cases. Also, increasing age, lower education level and spatial ability lead to slower performance. Finally, increasing age, higher level of spatial ability and education level and an internal locus of control, lead to a stronger preference for the directive Computer Assistant feedback style. These results correspond with findings discussed in Chapter 4 showing that the cooperative style was more effective and satisfactory and personal characteristics have a moderating effect on evaluating eHealth services with Personal Computer Assistants.

The study findings have an implication for the design of computer assistance for the support of remote collaborative troubleshooting. It is preferred for users with different personal characteristics in regard to spatial ability, age, education level and level of technical expertise to receive different types of feedback styles. Moreover, older adults experience more effort then the younger adults. Strikingly, amongst older adults the personal characteristics play a predominant role in the variance in performance. A future design-requirement is to alleviate this difference. Only when the feedback style is well geared to different users, collaborative troubleshooting will progress optimally. For example, the computer assistant offers novice older adults information on the domestic medical instrument in an instruction animation that attends to the lower level of spatial ability. Meanwhile, the experts receive from their computer assistant examples of past occasions which describe the common challenges of the older clients and possible solution describe in a layperson style.

When interpreting these results, we need to address an important issue related to the role of age in the use of eHealth services with Personal Computer Assistants. As described by Nichols and colleagues, age is an important variable in the use of technology (Nichols, Rogers, & Fisk, 2003). Aging affects cognitive abilities, which, in turn form covariates in the evaluation of technology. However, not everybody develops similarly over time and, illustratively, two persons with the same age can differ in their memory skills or spatial ability and thus experience technology as more or less challenging. Accordingly, our given indication of the older adults groups has some deficiencies in representativeness. In following studies that deal with older adults and their evaluation of the eHealth with Computer Assistants, we will aim at recruiting participants within a more distinct age bracket and provide a good overview of the cognitive characteristics that theoretically affect technology use.

In conclusion, we designed a usable Personal Computer Assistant for remote collaborative troubleshooting of domestic medical instruments. The assistants accommodate younger and older adults by providing different feedback styles, i.e., cooperative and directive. Accordingly, the use of Personal Computer Assistants can support patients troubleshoot domestic medical instruments in collaboration with remote technical specialists. Moreover, considering the personalized support for complex tasks, assistants could contribute to self-care adherence. We will discuss this in the coming chapters.

6

SELF-CARE AND MEDICAL ADHERENCE

In Chapter 4 and 5, we studied the influence of a Personal Computer Assistant applying cooperative and directive feedback on the troubleshooting of medical instruments, which are used monitoring of self-care activities. An additional way that Computer Assistants could contribute to self-care is by supporting medical adherence, which, in the developed countries, only averages 50%. To support medical adherence, we designed a Digital Diary with Personal Computer Assistance. We evaluated the influence of cooperative and directive feedback on the performance of daily care for a virtual patient, called the Health-Pal, by adults at home.

Results show that in relation to performing care activities, participants have a strong preference for the cooperative feedback style, which highly involved them in setting and executing the care plan. Consequently, in the coming chapters discussing Computer Assistants for self-care adherence, we will consider it as the most recommended Computer Assistant feedback style. This chapter is based on a previously published article.*

* Blanson Henkemans, O.A., Neerincx, M.A., Lindenberg, J., Mast, C.A.P.G van der. SuperAssist: Supervision of Patient Self-care and Medical Adherence. IEA 2006 Conference, July 10-14, 2006, Maastricht, the Netherlands.

6.1 INTRODUCTION

As outlined in the Chapter 1, in current health care service, patients are expected to become more empowered and self-supporting. Essentially, they need to be strongly involved in the care plan and perform self-care activities, such as maintaining a healthy diet, performing exercise and taking medication. As discussed in previous chapters, the use of Personal Computer Assistants offers interesting opportunities for self-care through the support of maintaining and troubleshooting of domestic medical instruments. In the current and coming chapters, we will focus more on how Personal Computer Assistants can contribute to adherence to self-care objectives.

6.1.1 *Self-care*

The World Health Organization defines self-care as "activities individuals, families, and communities undertake with the intention of enhancing health, preventing disease, limiting illness, and restoring health" (Bhuyan, 2004). Leventhal and colleagues have done extensive research on the importance of self-care with chronic patients (E. A. Leventhal, Hansell, Diefenbach, Leventhal, & Glass, 1996). The authors propose a framework for viewing and understanding the self-care process across different settings. In their framework, self-care is related to what patients do at home and work, by themselves and with friends and family to improve health and to prevent, treat and rehabilitate for acute and chronic diseases. Also, it includes how they perform self-monitoring and execute medical regimes as prescribed. Finally, they underlined the importance of context.

In later years, Leventhal and colleagues propose a categorization of self-care (SC), which consists of the following main points (Leventhal, Halm, Horowitz, Leventhal, & Ozakinci, 2004):

- **Regulatory SC, including routine health maintenance activities;**
- **Preventive SC, including practices like exercising, dieting, self-examination;**
- **Reactive SC, including self-initiated responses to symptoms that have not yet been labeled by a physician as an illness;**

- **Restorative SC, which is compliance to a professionally prescribed medication regimen.**

This categorization can help obtaining insights in self-care activities and determining what factors must be addressed when supporting self-care processes. Also, it can help in assessing the causes of low medical adherence. Especially, since various researchers in the medical field agree that patients and the health care service benefit from self-care, (Etzwiler, Rukeyser, Steinbock, Agins, & Bodenheimer, 2003; Kennedy, Rogers, & Bower, 2007; Leventhal et al., 2008; Lorig & Fries, 2006).

6.1.2 *Medical adherence*

Medical adherence is generally defined as the extent to which a patient's self-care activities matches with medical or health advice. In current health care service low adherence is a considerable bottleneck. As discussed in Chapter 1, the average rate of adherence across diseases and medications is just 50%, which underlines its gravity. Different personal characteristics influence medical adherence, including desire in participation in medical decision-making, locus of control, self-efficacy and personality traits.

Golin et al., state that the patient's participation in medical decision-making can improve its self-care. This concerns the desire for discussion with the physician and the desire for receiving information from the physician (Golin, DiMatteo, Leake, Duan, & Gelberg, 2001). Moreover, the authors developed a questionnaire measuring the patient's desire to participate in medical decision making (DPMD).

A study on the role Locus of Control (LOC) on medical adherence (O'Hea et al., 2005), showed that people with an internal locus of control believe that their own tasks determine the rewards that they obtain, while those with an external locus of control believe that their own behavior doesn't matter much and that rewards in life are generally outside of their control. The authors found that poorer adherence to a diabetic regimen were related to higher level of external LOC beliefs.

Different studies examined the influence of self-efficacy on medical adherence in patients and data suggests that efforts to improve self-efficacy could have medical and psychological benefits (Kaplan, Atkins, & Reinsch, 1984; Kneckt, 2000; Muehrer & Becker, 2005). Studies on the influence of personality traits, such as distinguished in the Factor Five model, or Big 5, on medical adherence showed that the trait conscientiousness is highly relevant to an enhanced self-care because of its predicting value concerning medical adherence (Christensen & Smith, 1995).

Finally, goal setting is considered to be related to medical adherence. In accordance with the goal setting principle (Maes & Karoly, 2005), patients make and execute plans and receive appraisal feedback on what they do well and on what needs to be improved. Research has shown that positive patient experience related to goal setting can stimulate to continual self-care. For example, Gloyd discusses different technological solutions, such as a website and a mobile application, which aim at positive user experience (Gloyd, 2003). Mainly, they address cognitive and emotional components, such as those listed above, by providing empathy, trust, familiar context, and user control. The author concludes that these technologies could well contribute to medical adherence.

Overall, research indicates that medical adherence can be stimulated by patient-tailored interventions. Thus, when developing eHealth with Personal Computer Assistants for medical adherence, we need to address the patient characteristics, demands, and context. Furthermore, adherence consists of a dynamic process aiming at improving the patient's behavior, which requires follow up on their performance.

6.1.3 *Personal Computer Assistant for Medical Adherence*

In Chapter 4 and 5, we studied the influence of Computer Assistants on the performance of maintenance and troubleshooting of medical instruments. Results show that Computer Assistants were beneficial and that different feedback styles influenced performance processes and outcomes. The cooperative style, which is oriented towards increased user participation, was most suitable for effective performance and it was considered most preferred. Our findings in Chapter 4 show that the directive feedback, which relieves the user of its tasks within its capacity, was most efficient. Finally, personal characteristics, e.g., demographics, cognitive abilities and personality traits, proved to explain variance in the evaluation of the proposed eHealth services with Personal Computer Assistant. When we look at self-care and medical adherence and our findings in Chapter 4 and 5, we can observe similarities in troubleshooting medical instruments and adhering to self-care activities. The similarities concern the involved actors' characteristics and context, use of multiple tools, information management, domain knowledge, and performance feedback. However, self-care adherence has supplementary aspects, namely, the role of satisfaction, motivation, need for behavioral change, and goal setting. This is illustrated in the following scenario.

John is currently engaged in maintaining a healthier lifestyle and taking his medication. However, he feels that improving his behavior and learning new habits is challenging. At home, without the supervision of his physician, he does not experience short-term progress, which is unsatisfying, lacks motivation, and easily relapse into old habits. Furthermore, he has insecurities about understanding the implications of his treatment prescription and the effectiveness of his self-care activities. His general practitioner suggests setting a number of personal self-care goals to motivate him. Also, he suggests measuring his glucose regularly and maintaining a diary of his self-care activities to get a better overview. Over time, these could help picking up the new habits and perceiving their relevance and outcomes.

Considering the discussed similarities and dissimilarities, we designed a Digital Diary with Personal Computer Assistants for medical adherence. The diary includes a virtual patient, called Health-Pal. By taking care of the Health-Pal in accordance with their Digital Diary, users can learn about how to develop a habit for daily care activities and self-care. Moreover, it enables us to objectively observe user behavior in a non-laboratory environment. The findings of the current study will be used in future studies with actual patients performing self-care. Consequently, the key question of this chapter reads:

How can a Personal Computer Assistant, applying cooperative and directive feedback through an animated avatar, support adherence to daily care activities?

To answer our question, this chapter discusses the design of a Digital Diary with

Health-Pal. In addition, it discusses the evaluation of different feedback styles on the performance of daily care activities by adults, in the age category that are more prone to lifestyle and chronic diseases, from their home. Additionally, we will study how the use of Personal Computer Assistants for self-care differs from supporting troubleshooting of domestic medical instruments.

6.2 DIGITAL DIARY WITH HEALTH-PAL

Following a scenario-based design approach (Rosson & Carroll, 2002), we designed a Digital Diary. In accordance with their diary schedule, people take care of their personal virtual patient called the Health-Pal (Figure 6.1). The aim of the Health-Pal is to help patients set goals, make treatment planning, and learn from the care giving experience. Moreover, by offering support in a fun way, it could facilitate positive user experience and stimulate medical adherence.

6.2.1 *User Interface*

The participants can access their Digital Diary and Health-Pal on their computer at home through the Internet. As illustrated in Figure 6.2, they can care for the virtual patient in the patient window. Taking care for the patient consists of instructing it to perform self-care activities, such as performing exercise, consuming a meal, and taking medication. Also, they could give it attention, i.e., play a game or have a conversation. The actions are executed by clicking on the relevant button around the virtual patient image.

Each activity has its specific positive or negative impact on the virtual patient's calorie balance, weight, mood and overall health condition. Illustratively, exercising decreases calories, but too much intense exercise is negative for the patient's mood. Eating a snack can be very satisfying, i.e., increase the mood, but also increases the calorie number. The participant clicks on an activity and it will appear in the queue at the right. Bellow the queue, the future status of the patient is calculated accordingly. An activity can also be removed from the queue, by selecting it and pressing the 'remove" button. When all desired activities are in the queue, the participant pushes the "Execute" button to finally execute the activities. In accordance with the new weight and mood, as illustrated in Figure 6.4, the image of the Health Pal will change.

The model behind the treatment for the Health-Pal is as follows. At day one, the virtual patient weighs 83 kilo, has an excess of 2500 calories and an overall health of 10. Every day, the patient will consume its daily 2500 calories and burn 2500 calories through daily activities. Moreover, its mood decreases by 15. The user can decrease the excess calorie by performing light (-500), medium (-1000), or intensive (-1500) exercise or taking compensating medication. Light (+10 mood) and medium (+5) exercise increase the mood, but intensive exercise decreases the mood (-5). Taking medication also decreases the mood. Moreover, having a snack increase the number of calories (+500) but also contributes to the patient's mood (+15). Finally, by giving the patient attention, the mood will improve by 15. For example, as illustrated in Table 6.3, when the user cares for one day by instructing the patient to have a snack, medium exercise, take a compensating pill that decreases the calories, and by giving attention, the patient will improve the calorie balance, mood and, as a result, the overall health. In the example in Table 6.1, the health of the virtual patient is based on the starting health value of 35, plus the sum of the moods and minus the amount of calories separated from calorie balance divided by 100. Thus, 35 + 19 – 15 = 39.

TABLE 6.1

Virtual patient treatment model at beginning of the week.

	DAY	Calories	Burn_Calories	Mood
Day	1			
Nutrition				
Daily nutrition (+2500al)	1	2500		-5
Have snack (+500cal)	1	500		15
Calories_tot	3000			
Weight (kg)	81			
Calories_balance	1500			
Calories_direction (-1=<x=<1)	1			
Exercise				
Daily movement (-2500cal)	1		2500	
Light exercise (once a day -500cal)	0		0	0
Medium exercise (once a day -1000cal)	1		1000	5
Intensive exercise (once a day -1500cal)			0	0
Burned_calories_tot	4000			
Medication				
Compensating pills (-500cal)	1		500	-1
Compensating pills (+500cal)		0		0
Give attention	1			15
Mood	19			
Health_current	39			

In the administrator screen (Figure 6.3), the experiment leader can add users and manage their account, online schedule, and feedback condition, i.e., co-operative or directive. Furthermore, he can monitor the participants' performance, concerning the times participants logged in according their schedule, the performance of the care tasks, and the health of the virtual patient.

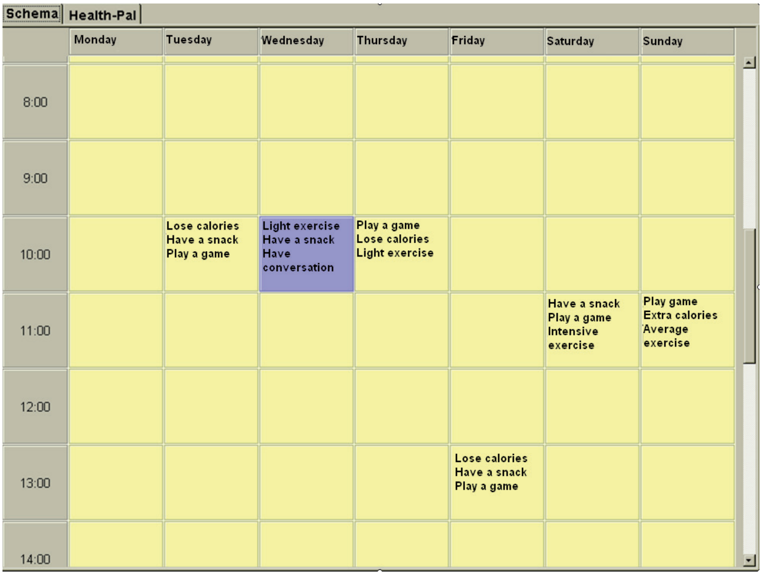


FIGURE 6.1

The online schedule screen with care tasks and current time (dark square)

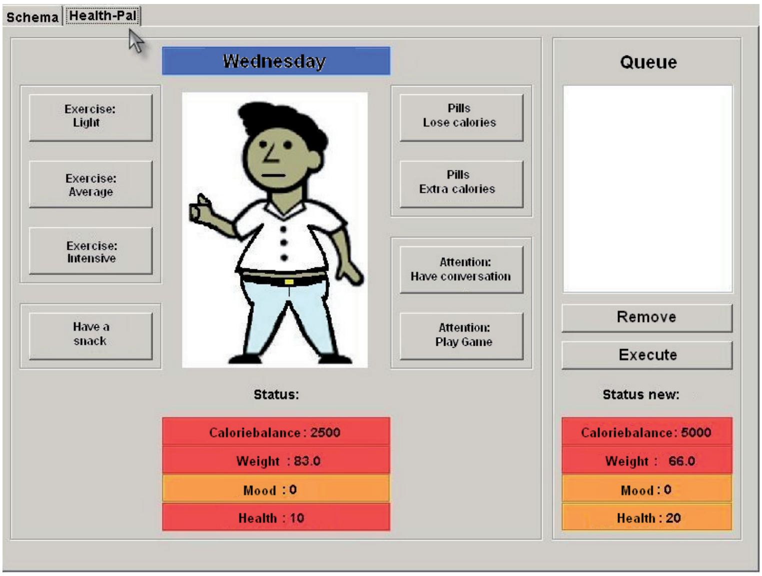
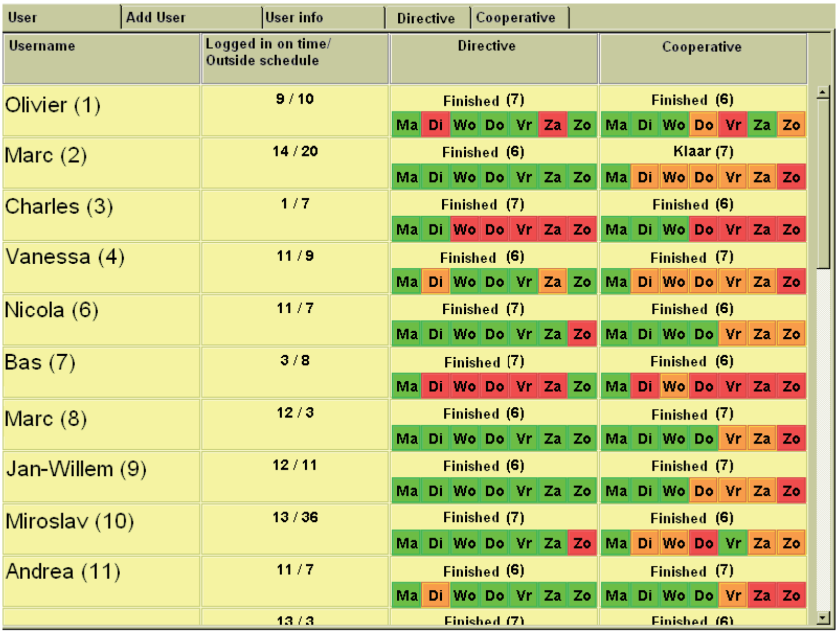


FIGURE 6.2

The virtual patient screen with patient, care activity buttons (right) and activity queue (right).



Username	Logged in on time/ Outside schedule	Directive	Cooperative
Olivier (1)	9 / 10	Finished (7) Ma Di Wo Do Vr Za Zo	Finished (6) Ma Di Wo Do Vr Za Zo
Marc (2)	14 / 20	Finished (6) Ma Di Wo Do Vr Za Zo	Klaar (7) Ma Di Wo Do Vr Za Zo
Charles (3)	1 / 7	Finished (7) Ma Di Wo Do Vr Za Zo	Finished (6) Ma Di Wo Do Vr Za Zo
Vanessa (4)	11 / 9	Finished (6) Ma Di Wo Do Vr Za Zo	Finished (7) Ma Di Wo Do Vr Za Zo
Nicola (6)	11 / 7	Finished (7) Ma Di Wo Do Vr Za Zo	Finished (6) Ma Di Wo Do Vr Za Zo
Bas (7)	3 / 8	Finished (7) Ma Di Wo Do Vr Za Zo	Finished (6) Ma Di Wo Do Vr Za Zo
Marc (8)	12 / 3	Finished (6) Ma Di Wo Do Vr Za Zo	Finished (7) Ma Di Wo Do Vr Za Zo
Jan-Willem (9)	12 / 11	Finished (6) Ma Di Wo Do Vr Za Zo	Finished (7) Ma Di Wo Do Vr Za Zo
Miroslav (10)	13 / 36	Finished (7) Ma Di Wo Do Vr Za Zo	Finished (6) Ma Di Wo Do Vr Za Zo
Andrea (11)	11 / 7	Finished (6) Ma Di Wo Do Vr Za Zo	Finished (7) Ma Di Wo Do Vr Za Zo
	13 / 3	Finished (7)	Finished (6)

FIGURE 6.3

The administrator and monitoring screen with participants' list and adherence performance (gray: performed activities as planned, light gray: performed activities but deviated from plan, dark gray: failed to perform activities) with cooperative and directive feedback.

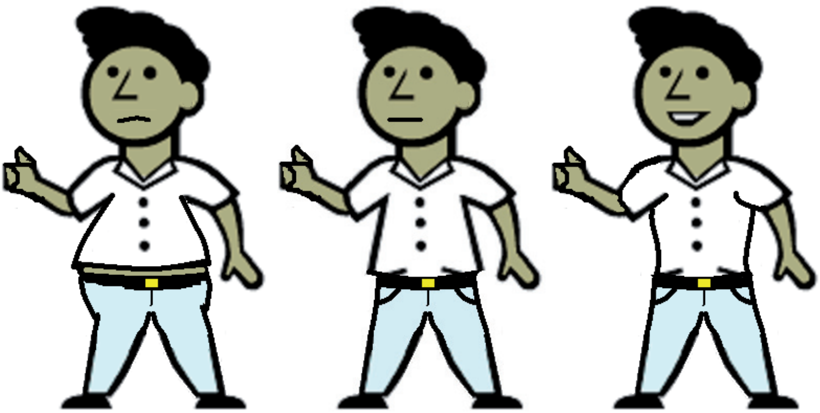


FIGURE 6.4

Different weight and mood conditions of the Health Pal. From left to right: overweight and unhappy, normal weight and neutral mood, and fit and happy.

6.2.2 *Cooperative and Directive Feedback*

The Digital Diary and Health-Pal application focuses on the self-care categories. These consist of monitoring the patient personal profiles and medical activities, stimulating and facilitating self-care tasks, such as diets, exercise, and medication, and offering information for better understanding of practical implications of self-care. Moreover, in corresponding to previous chapters, the application includes a Personal Computer Assistant, which provides cooperative and directive feedback.

The feedback is offered through the diary and virtual patient components. The cooperative feedback aims at monitoring the virtual patient's profile and suggesting care activities and providing feedback to improve the virtual patient's health. In practice, the participants received guidelines at the start of the study on how to get the virtual patient in a healthy condition. Based on the guidelines, they could indicate in their Digital Diary which care activities they wanted to execute and when they wanted to perform them. During the week, all the buttons in the virtual assistant window were active. By adding and removing activities to the queue and changing the future status, the participants could proactively select the care activities. Consequently, the participants were free to deviate from their planning if they felt this could improve the health of the patient.

The directive feedback aims at monitoring the patient's profile and decides on the ideal care tasks to improve the virtual patient's health. The participants were obligated to follow these tasks. The participants received no guidelines at the beginning of the study. Instead, the ideal activity planning was set for them and they only needed to indicate when they wanted to take care of the virtual patient. As a constraint, the participants could only push the buttons that were indicated in their schedule and could not compensate, in later days, for the missed activities.

During the current study, we will evaluate if a Personal Computer Assistant can support commitment and adherence to daily care activities in a satisfying way. We will look at people in the age where the increase overweight and lifestyle related chronic disease is the greatest, i.e., between 30 and 64, and are faced explicitly with the challenges of adherence to daily healthy lifestyle objectives (Dotinga & Picavet, 2006). The discussed literature on self-care and medical adherence indicates that medical adherence is stimulated by providing information, high level of participation, and setting personal goals. Consequently, we expect that the cooperative condition, will lead to better performance of daily care activities. Also, it will lead to more positive user experience and commitment. Additionally, we expect that the personal characteristics, i.e. demographics, computer experience, desire for participation in medical decision-making (DPMD), self-efficacy (SE), locus of control (LOC), and the Five Factor personality traits, will explain variance in the performance of the daily activities with the use of the Digital Diary with Health-Pal.

6.3 METHOD

Twenty-eight adults (14 male and 14 female) aged between 36 and 59 (M=47.21, SD=6.76) participated in our experiment. Twenty-three persons were employed (11 full-timers and 12 part-timers). The educational level varied between university degree and lower general secondary school degree, and computer skills varied between 1, low, i.e., never work with computers, and 4, high, i.e., work with computers daily (M=3.54, SD=.84).

The participants had to take care of their virtual patient for a period of two times one week (6 days). At the beginning of the week, the virtual patient is overweight and has to perform care tasks, i.e. dieting, exercise, medication and receiving attention, to get back into shape and improve the mood. One week the participants received cooperative feedback and the other week they received directive feedback. The second week the patient's health state was restored to its initial (unhealthy) state and the conditions are cross balanced.

At the beginning of the week the participants had to make a schedule of that week. In the schedule, they had to indicate for each day at what time they would care for the virtual patient and the schedule was copied in the Digital Diary. Performing activities with the patient was only possible if the participants logged in at the time indicated in the online schedule.

After the two weeks of the study, we surveyed online the preference for feedback condition in relationship to daily care activities. These covered commitment to the care plan, the care for virtual patient, and self-care. Table 6.2 lists examples of the survey questions.

TABLE 6.2

Examples of preference questions in closing survey.

Measure	Example question
Commitment to Digital Diary	How important was it for you to address the diary when scheduled?
Commitment to care for virtual assistant	How important was it for you that the virtual patient was in good health?
Preference for feedback when taking care for virtual patient	While taking care of the virtual patient, my preference went out to: 1 Set tasks based on guidelines and execute them according own insights 2 Execute preset tasks
Preference for feedback when performing self-care	When performing self-care, my preference would go out to: 1 Set tasks based on guidelines and execute them according own insights 2 Execute preset tasks

To analyze the effect of the feedback styles on performing daily care activities, i.e., adhering to the diary and caring for the virtual patient, we did a repeated measure ANOVA. To analyze satisfaction, we did a Chi-square analysis on the participants' preference. Finally, to explain the variance in performance by personal characteristics, we did a regression analysis with 12 predictors. These were age, education level, employment, computer experience, self-efficacy, locus of control, five factor personality traits (i.e., openness, conscientiousness, extraversion agreeableness and neuroticism), and desire for participation in medical decision-making*.

* For this chapter, we conducted an improved analyses of the data in relation to the original article for IEA 2006 Conference.

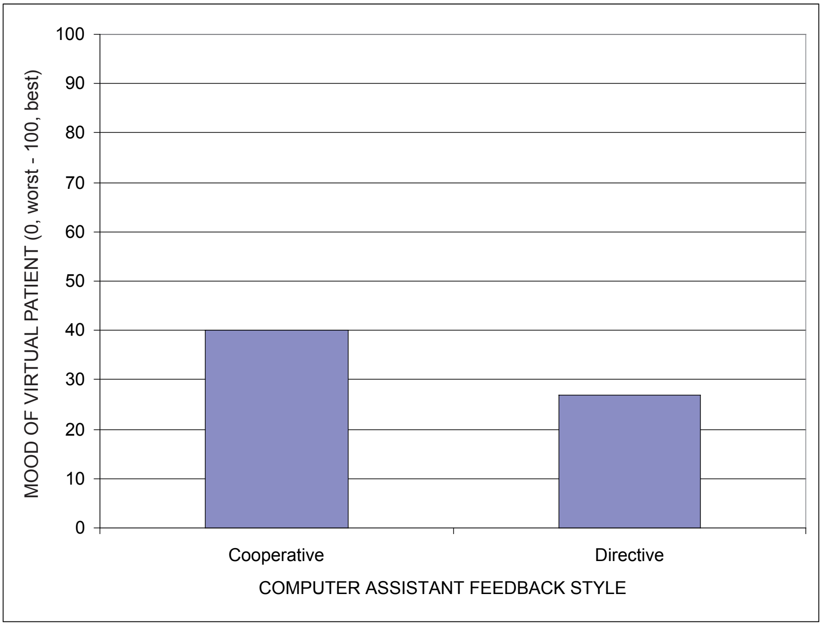
6.4 RESULTS

In regard to adherence, we analyzed the influence of two feedback conditions on following the schedule in the Digital Diary over a period of 6 days each. Results show that participants' adherence level to the schedule was similar when receiving cooperative feedback (*M*=5.25, *SD*=1.23) and directive feedback (*M*=5.29, *SD*=1.35).

Concerning the care for the virtual patient, as illustrated in Figure 6.5, analysis showed that, on a scale from 0 (good) to 100 (worst), participants receiving cooperative feedback were more successful in getting the patient in a good mood (*M*=26.96, *SD*=32.84) than participants receiving directive feedback (*M*=39.96, *SD*=36.45), $F(1,25)=5.50$, $p<.05$. Further, we did not find substantial influence of feedback style on the quality of care for the virtual patient, concerning weight or health condition.

FIGURE 6.5

Mood of virtual patient after one week when receiving cooperative (*M*=39.96, *SD*=36.45) and directive (*M*=26.96, *SD*=32.84) feedback, $F(1,25)=5.50$, $p<.05$.



Of the 28 participants, 21 completed the closing survey regarding preference. As listed in Table 6.1, participants felt most committed to the care of the virtual patient when receiving cooperative feedback. In turn, 20 respondents indicated they felt more committed to both the schedule itself, $\chi^2(1)=17{,}19$, $p<.001$, and the care for the virtual patient, $\chi^2(1)=17{,}19$, $p<.001$, when the assistant gave cooperative feedback. Moreover, 20 respondents expressed preference for cooperative feedback when caring for the virtual patient, $\chi^2(1)=17{,}19$, $p<.001$, and, correspondingly, 18 respondents indicated they would prefer cooperative feedback when performing self-care, $\chi^2(1)=17{,}74$, $p<.05$.

TABLE 6.3:

χ^2 test statistics on commitment and preference regarding Computer Assistant feedback style condition, with an expected value of 10.5.

Commitment		
	Cooperative	Directive
Schedule[1]	20	1
Virtual patient[1]	20	1
Preference		
	Cooperative	Directive
Care of Virtual Patient[1]	20	1
Self-care[2]	18	3

[1] $\chi^2(1)=17{,}19$, $p<.001$
[2] $\chi^2(1)=17{,}74$, $p<.05$

Analysis did not show that personal characteristics moderated the evaluation of the Computer Assistant. Presumably, this is due to the small variance in the outcome variables, i.e., adherence to the schedule, care for the patient, and preference for feedback condition.

6.5 DISCUSSION

The application with Digital Diary and virtual patient, the Health-Pal, proved to be useful for commitment and adherence to daily care activities in a satisfying way. Over a period of two weeks, we successfully observed participants' care behavior remotely. This gives us a good overview of the adherence to the care plan and the care for the patient. In addition, we deployed the cooperative and directive feedback conditions in support of medical adherence. Results show that the feedback did not substantially influence the adherence to the Digital Diary and the care of the virtual patient. On both aspects, the participants scored very high. Besides the fact that participants regulated the mood of the virtual patient better when receiving cooperative feedback, the participants had a strong preference for the cooperative feedback style, i.e., participants were involved in the care plan, in regard to commitment to the diary and care for the virtual patient. Strikingly, participants also experience preference for the cooperative feedback style in the case of self-care.

When reading these findings we need to take two issues in mind. First, a previous study underlines the importance of satisfaction and commitment in medical adherence (Wahl et al., 2005), the current bottleneck in self-care. Consequently, from the findings presented in this chapter, in accordance with findings in Chapter 4 and 5, we can gather that the cooperative feedback style would be most suitable for self-care.

Second, according to the literature, commitment and participation in the care plan improve medical adherence and the self-care quality (Golin et al., 2001). In our study, there was a distinct difference between the conditions concerning experienced preference. However, we did not find significant differences in the adherence. Considering the high adherence scores, the lack of results can most likely be attributed to a ceiling effect. We assume that the effect of the feedback condition on performance was masked. As a result, we expect that research over a longer period of time and with a larger number of participants will show an effect of feedback style on variance in medical adherence and quality of self-care.

Our current study gave us good insights in the feasibility of eHealth with Personal Computer Assistants. Still, designing Personal Computer Assistants for adherence to self-care objectives differs from care for a virtual patient. Consequently, in the coming chapter, we will focus more on self-care. Amongst others, we need to study how to stimulate health literacy, i.e., the capacity to grasp health information needed to make appropriate health decisions (Morrow et al., 2006). Moreover, occasionally, patients experience health critical situations, e.g. suffering from a hypoglycemic attack. This impacts their cognitive resources and, as discussed in Chapter 4 and 5, could influence the requirements for Personal Computer Assistant feedback styles. Chapter 7 will discuss the study in lab setting of an Adaptive Computer Assistant addressing these two issues. In addition, we need to address improvement of personal lifestyle, through goal setting over a longer period of time. Chapter 8 discusses a one month randomized controlled trial of a Persuasive Computer Assistant. It supports adherence to maintaining a healthy lifestyle in accordance with personal goals by providing feedback according the motivational interviewing concept and accompanied with facial expressions.

7

* Blanson Henkemans, O.A., Rogers, W.A., Fisk, A.D., Neerincx, M.A., Lindenberg, J., and Mast, C.A.P.G. van der. Usability of an Adaptive Computer Assistant that Improves Self-Care and Health Literacy of Older Adults. Methods of Information in Medicine, 2008; 47, pp. 82 – 88.
Bojic, M., Blanson Henkemans, O.A., Neerincx, M.A., Mast, C.A.P.G. van der, and Lindenberg, J. Effects of Multimodal Feedback on the Usability of Mobile Diet Diary for Older Adults. Accepted for HCI International 2009, San Diego, CA, USA.

SELF-CARE IN NORMAL AND HEALTH-CRITICAL SITUATIONS

The previous chapter showed that Personal Computer Assistance for self-care adherence is generally better when providing cooperative feedback, which aims at high patient involvement, instead of directive feedback, which aims at a quick problem solving. Occasionally patients can experience health critical situations creating a trade-off between, on the one hand, supporting positive user experience and contributing to health literacy and, on the other hand, efficiently resolving health critical situations. Therefore, we designed a Digital Diabetes Diary with a Computer Assistant that adapts its feedback style to the patient's situation. We evaluated the Adaptive Computer Assistant in a smart home lab with older adults engaged in scenarios reflecting normal and health critical situations.

Results show that the adaptive Assistant was more effective in dealing with normal and health critical situations, and, generally, led to more time efficiency, in comparison to a fixed cooperative Assistant. Moreover, the use of the Digital Diabetes Diary led to an increase in diabetes knowledge. Based on the recommendations of the participants, which were expressed in the closing interview, we designed and evaluated a mobile multimodal diet diary. Results showed that older adults interacting with diary preferred textual and graphical feedback and that speech lead to a decrease in preference. For both the home computer and the mobile diary, participants' personal characteristics (i.e., age, gender, spatial ability, working memory, memory span, vocabulary, perceptual speed, and locus of control) influenced the self-care process and outcomes. In the next chapter, we will use our findings in a study on the effect of an Online Lifestyle Diary with Persuasive Computer Assistant on adherence to self-care activities in the field. This chapter is based on earlier published articles.*

7.1 INTRODUCTION

Various studies proved the importance of ICT use in the health care service (Larizza et al., 2006). These studies discuss how ICT can be implemented in the health care service and support medical specialists. However, there is little research on how this technology can support patients' self-care with the use of computer feedback (Nooijer et al., 2005). This chapter discusses how such a Computer Assistant can be designed for support of patients' self-care activities and evaluated for in normal and health critical situations.

7.1.1 *Health Literacy*

In Chapter 6, we discussed the support of Computer Assistants for self-care adherence and an aspect of influence that surfaced, but which was not further discussed, is health literacy. The National Network of Libraries of Medicine defines health literacy as the ability to understand prescriptions, medical education brochures, doctor's directions and consent forms, and the ability to negotiate complex health care systems. Foremost, it requires a complex group of reading, listening, analytical, and decision-making skills, and the ability to apply these skills to health situations (United States Department of Health and Human Services, 2000).

Andrus and colleagues pointed out that inadequate health literacy leads to poorer health status. This is due to lack of knowledge about medical care and medical conditions, comprehension of medical information, and understanding and use of preventive services. In turn, this leads to poorer compliance rates (Andrus & Roth, 2002).

As a result, it is suggested to consider and accommodate the patients' preferences, based on their experience with health instructions and cognitive abilities (Baker, 2006; Morrow et al., 2006). Examples of abilities are mental speed and working memory. In line with these findings, medical instructions should involve the patient, be offered elaborately, and facilitate step wise processing.

7.1.2 *Health Critical Situations*

Accommodating patients' experience and cognitive abilities becomes more complex in case of health critical situations. For example, diabetes type II patients occasionally experience hypo- and hyperglycemic attacks. Respectively, a low glucose level can cause increased anxiety, sweating profusely and hunger, and a high glucose level can cause fatigue and blurred vision.

These distracting factors burden the patient's cognitive resources (Werther & Schnieder, 2005). Illustratively, fatigue can lead to decrease in alertness due to concentration difficulties, error making and slow reaction. Moreover, fatigue can negatively affect cognitive control, which leads to inadequate response and adjustment to changes in the environment (Gaillard, 2003).

Bailey and colleagues studied the effects of interruptions on task performance, while interacting with user interfaces (Bailey, Konstan, & Carlis, 2001). The results of their experiment show that distractions lead to slower performance, anxiety and increase in workload. Thus, when designing a user interface, which mitigates health critical situations, it is important to address these distracting factors.

In summary, the need for efficient problem solving may outweigh the importance of patient empowerment, offering elaborate medical instruction, and facilitating step wise processes.

7.1.3 *Adaptive Computer Assistant*

The results in the previous chapter indicate that the cooperative Computer Assistant feedback style is effective for self-care adherence. However, it is required to address the trade off between, on the one hand, supporting positive user experience and contributing to health literacy and, on the other hand, efficiently resolving health critical situations. This is illustrated in the following scenario.

To get a good overview of his self-care activities and their outcomes, John enters dietary activities in his Digital Diary on his desktop computer. His Personal Computer Assistant provides cooperative feedback, which has an explanatory *and educating character and stimulates user participation. Recently, he ate irregularly resulting in overeating. This trigged a hyperglycemic attack, which is accompanied with frequent urination, thirst and difficulties with concentrating. As a result, John experiences the otherwise helpful elaborative cooperative feedback as patronizing and inefficient.*

To address the posed issue, we designed a Computer Assistant for the supervision of diabetics' self-care in normal and health critical situations. The assistant monitors the patient's digital diary. As discussed in Chapter 1, based on the collected data, the assistant provides feedback to support self-care and mediates the communication between the patient and the (remote) medical specialists.

The Computer Assistant must enable self-care concerning enhancing health literacy and assisting in instances where acute treatment is required. In our design this was translated in two aspects. First, it supports knowledge of diabetes and improves self-care by offering information on diabetes' background, cause, and treatment. Second, it diagnoses the health situation (e.g., hypo- or hyperglycemic attack) and suggests acute treatment accordingly.

Previous chapters discuss the influence of different Computer Assistant feedback styles on troubleshooting and achieving self-care objectives. The assistant applied a cooperative feedback style, i.e., it has a coaching character, explains and educates the patient, and expects high participation of the user, or it applied a directive feedback style, i.e., it has an instructing character with brief reporting and expects low participation of the user. Results showed that the cooperative assistant was more effective and satisfactory, whereas the directive assistant was more efficient. Furthermore, personal characteristics, such as demographics, cognitive abilities and personality traits, proved to explain variance in the performance of self-care activities and outcomes. Based on these findings we developed an Adaptive Computer Assistant that switches from cooperative to directive feedback style depending on the patient's health situation, hence our research question reads:

How can an Adaptive Computer Assistant, applying cooperative and directive feedback in text and images, support normal and health critical situations and contribute to health literacy?

To answer our question, this chapter discusses the design of a Digital Diabetes Diary with Adaptive Computer Assistant. Subsequently, it discusses the evaluation of different Computer Assistant types on self-care activities and outcomes, including health literacy. In addition, this chapter discusses the study of a multimodal Mobile Diet Diary. Based on the evaluation of Digital Diabetes Diary, we designed a diet diary that runs on a mobile device. The interaction with the diary takes place in text, images and speech, and we evaluated the influence of the different modalities on the usability of the diary and health literacy. These studies took place in Smart Home Labs, i.e., the Georgia Tech Aware Home and the TNO Experience Lab, respectively, with healthy older adults using the diaries according to scenarios. We will conclude with the discussion of the result of both studies.

7.2 DIGITAL DIABETES DIARY WITH ADAPTIVE COMPUTER ASSISTANT

The Computer Assistant interacts with the patient through a Patient User Interface. As illustrated in Figure 7.1, the interface consists of a Digital Diabetes Diary, an interaction frame and a traffic light. The user fills in the diary daily, concerning dietary and physical activities, medication and bodily symptoms, such as glucose level and mood. The assistant monitors the Diabetes Diary, assesses the patients' glucose level and symptoms, and gives feedback according to a number of rules (Figure 7.2). These rules originate from American Diabetes Association documentation (American Diabetes Association, 2004) and were written in collaboration with diabetes experts from the Leiden University Medical Center (LUMC), in the Netherlands, who supervised the practical validity.*

* We want to thank Amy Ahluwalia for her valuable interviews with diabetic patients and specialists.

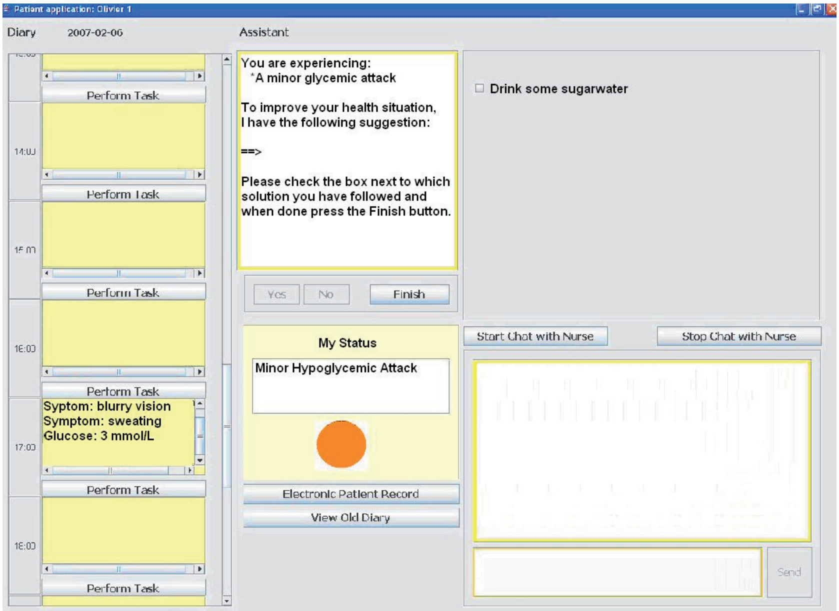


FIGURE 7.1

Patient interface with Digital Diabetes Diary and Computer Assistant.

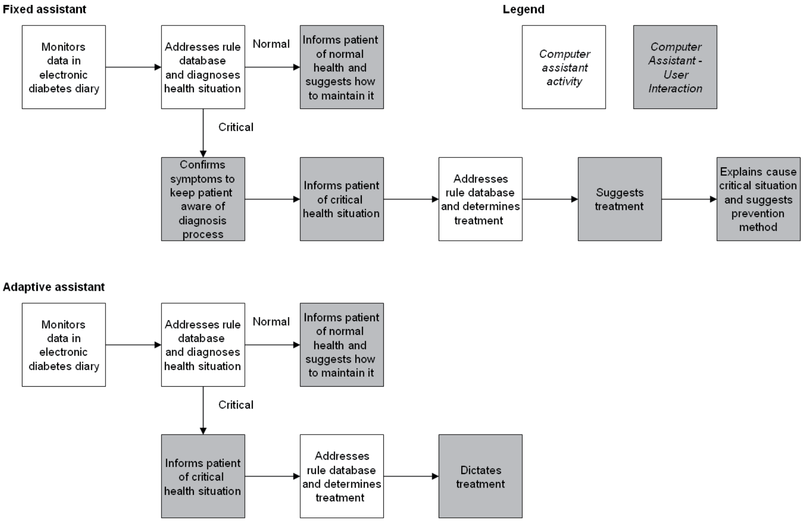


FIGURE 7.2

Diagram of fixed and Adaptive Computer Assistant behavior. Adaptive Computer Assistant does not involve the participant in the diagnosis process nor clarify how the critical situation was caused and how to prevent it in the future. Fixed assistant stays cooperative and does give this “educational” feedback.

7.2.1 *User Interface*

To illustrate the function of the Computer Assistant, Figure 7.1 shows the patient has a glucose level of 3 mmol/L and experiences blurry vision and excessive sweating. The assistant diagnoses that the patient suffers from a minor hypoglycemic attack. It informs the patient of his or her current health situation and suggests a treatment, namely, to drink a glass of sugar water. Finally, it explains what the cause was of the critical situation and indicates how it can be prevented in the future. In brief, the behavior of the Patient Assistant is programmed as follows:

If 3 <glucose level < 4 mmol/L and Symptoms = Blurry vision & Sweating
Then Health_Situation = Minor hypoglycemic attack
Suggestion = "Drink glass of sugar water."
Cause_and _Prevention = "Hypoglycemic attacks are caused by a low level of glucose in your blood. This can be prevented:

- *Mind your nutrition*
- *Organize daily schedule to prevent stressful situations*
- *Take glucose measurements frequently."*

The traffic light represents the current health situation of the patient. A green light is shown when the patient is in a normal health situation. An orange light is shown when in a minor health critical situation (glucose level between 3 and 4 mmol/L and between 8 and 10 mmol/L). A red light is shown when the patient has a severe health critical situation (glucose level below 3 and above 10 mmol/L).

7.2.2 *Adaptive Computer Assistant*

For stimulating medical adherence, the cooperative assistant would be more preferable. However, if the patient is feeling unhealthy, the focus should be on acute treatment and restoring health. In this case, a directive assistant would more beneficial. To combine the advantages of both feedback styles, we propose an adaptive assistant that adapts its feedback to the patient's health situation (Table 7.1).

TABLE 7.1

Fixed and Adaptive Assistant Types in Normal and Health Critical Situations.

Assistant type	Normal situation	Health-Critical situation
Fixed	Cooperative feedback	Cooperative feedback
Adaptive	Cooperative feedback	Directive feedback

Consequently, we will evaluate if an Adaptive Computer Assistant can support older adults' self-care, concerning enhancement of health literacy and acute treatment in an effective, efficient and satisfying way. First, we will determine if the adaptive assistant is more usable than a fixed assistant, which does not adjust its feedback style to the patient's situation. Second, we investigate whether the assistant style influences health literacy. Finally, due to its innovative character, implementation of eHealth may be prone to misapprehension, errors and, eventually, abandonment (Gitlin & Burgh, 1995). This applies specifically to older users, who require more time to adopt technology, due to their decline of cognitive, physical and sensory functions (Mayhorn, Rogers, & Fisk, 2004). In accordance, we assess whether personal characteristics, including personality traits and cognitive abilities, explain variance in the performance of self-care activities and outcomes.

We formed our initial expectations with the assumption that the use of health technologies promised to contribute to the quality of self-care (Larizza et al., 2006). In addition, given that the Adaptive Computer Assistant's feedback style is designed for the patient's health situation, it could lead to a higher level of usability (Streefkerk et al., 2007). Because the fixed assistant will continuously keep coaching, advising and educating the participants, it might lead to a higher level of diabetes knowledge. Lastly, in line with our discussion of Human Factors in section 2.3.2, we anticipate that people have different personal characteristics which can influence the way the participants perform self-care activities with the use of the Digital Diary with Personal Computer Assistant effectively, efficiently and with satisfaction.

7.3 METHOD

Participants were an ethnically diverse sample of 28 older adults, 15 male and 13 female, 20 Caucasian and 8 African American, between the ages 61 and 75 (*M*=67, *SD*=2.76), without diabetes type II. They cleared a visual acuity test at the level of 20/40 for far and near vision. Participants received financial compensation for their participation in this study which lasted 3 hours. The study protocol was approved by the Georgia Tech IRB.

Participants were tested on a number of cognitive abilities, including vocabulary (Shipley, 1986), memory span, perceptual speed (Wechsler, 1981), and spatial ability. Also, we measured participants' locus of control, which refers to two types of people: those with an internal locus of control (i.e., attribute events to their own control), and those with an external locus of control (i.e., attribute events to external circumstances) (Rotter, 1954).

During the experiment, participants performed tasks on the Patient User Interface according to eight scenarios. Scenarios alternated from a normal to a health critical situation. The four health critical scenarios described hypoglycemic and hyperglycemic attacks. We emphasized that in these scenarios the participant was not feeling well and imperative that the scenario be completed quickly. We used time pressure to increase the participants' mental effort and stress with the use of a timer facing the participant, which counted from 5 minutes backwards and sounded a beep every 30 seconds. Participants performed four scenarios with each Computer Assistant types. Half of the participants in the group interacted during the first four scenarios with the fixed assistant and during the latter four scenarios with the adaptive assistant. The other half interacted with the converse.

We observed the influence of the Computer Assistant types on the experienced usability, concerning effectiveness, efficiency, and satisfaction. Effectiveness was measured by logging the errors made while completing the scenarios. Errors participants made varied from entering the wrong tasks in the diary to incorrectly answering the Computer Assistant's questions. For example, during the diagnosis procedure, the Computer Assistant verified with the participants if they were in a type of mood, e.g., shaky, which they declined, even though it was described in the scenario. Efficiency was measured by logging the time required to fulfill the scenarios and mental effort experienced. Mental effort concerns the resources required to perform the task and was measured using the NASA-TLX (Hart & Stavenland, 1988). Participants' were also asked to indicate which type of assistant (fixed or adaptive) they preferred. After four and, again, after eight scenarios, participants completed a diabetes knowledge survey, containing eight multiple-choice questions dealing with aspects of type II diabetes. Exemplary questions are presented in the Table 7.2. Moreover, we studied the explanatory value of the tested cognitive abilities (memory span, vocabulary, perceptual speed, spatial ability) and personality traits (locus of control) on the performance of self-care activities and outcomes. Finally, at the end of each study, we interviewed participants and asked them the open question if they had "any general suggestions about how we could improve our study of supervision of older diabetes patient's self-care".

TABLE 7.2

Examples of health literacy questions

Stress has negative effect on your health and especially with diabetic patients:

- ☐ Stress causes great fluctuation in your glucose level and it's hard to predict the outcome
- ☐ Stress causes adrenaline and activation of the organs. This can cause a hypoglycemic attack
- ☐ Stress causes indifference and laziness and increases the chances of a hyperglycemic attack
- ☐ Stress causes a great urge to eat sweets which is bad for the glucose level
- ☐ I don't know

If your glucose level is too low, symptoms are:

- ☐ Frequent urinating and thirst
- ☐ Symptoms change over time
- ☐ Hunger, trembling and sweating
- ☐ Rapid pulse and sweating
- ☐ I don't know

The best way to prevent hypers and hypos is by:

- ☐ Eating healthy and exercise frequently
- ☐ Retaining from eating sweets and preventing stressful situations
- ☐ Eating hydrate-rich meals frequently
- ☐ Patients cannot do anything about glucose level in the blood
- ☐ I don't know

To validate our simulation of health critical situations, we performed a paired sample t-test comparing participants' subjective rating of time pressure and mental demand during the scenarios. To evaluate the Computer Assistants' effectiveness, efficiency, and contribution of health literacy, we performed a repeated measures ANOVA with the factors of health situation (2 levels: Normal and Health Critical) and assistant type (2 levels: Fixed and Adaptive) on number of errors made, time, effort, and number of diabetes type II related questions correct. To assess if participants had a preference for the adaptive assistant, we performed a Chi square test. To determine whether there was a relationship between personal characteristics and the performance of self-care activities and outcomes we conducted multiple regression analyses on the participants' performance data with 7 predictors. The predictors were gender, age, vocabulary, perceptual speed, memory span, spatial ability, and locus of control.

7.4 **RESULTS**

During the health critical situations, experienced time pressure ($t(27)=-4.98$, $p<.001$) and mental demand ($t(27)=-3.03$, $p<.05$) were both significantly higher than during the normal health situations. We aimed at putting the participants in a time pressurized and stressful situation and these results validate that manipulation.

The effectiveness of the two Computer Assistants in relation to the health situation is shown in Figure 7.3. Mainly, participants made more mistakes when experiencing a simulated health critical situation ($M=.86$, $SE=.13$) than when experiencing a normal situation ($M=.16$, $SE=.01$), $F(1,27)=36.06$, $p<.001$. Secondary, there is a interaction effect and participants interacting with an adaptive assistant made significantly fewer errors ($M=.54$, $SE=.11$) than with a fixed assistant ($M=1.19$, $SE=.15$), $F(1,27)=4.94$, $p<.05$.

FIGURE 7.3

Mean number of errors, with standard error bars, made in normal and health critical situations with a fixed and Adaptive Computer Assistant, with interaction effect, $F(1,27)=4.94$, $p<.05$.

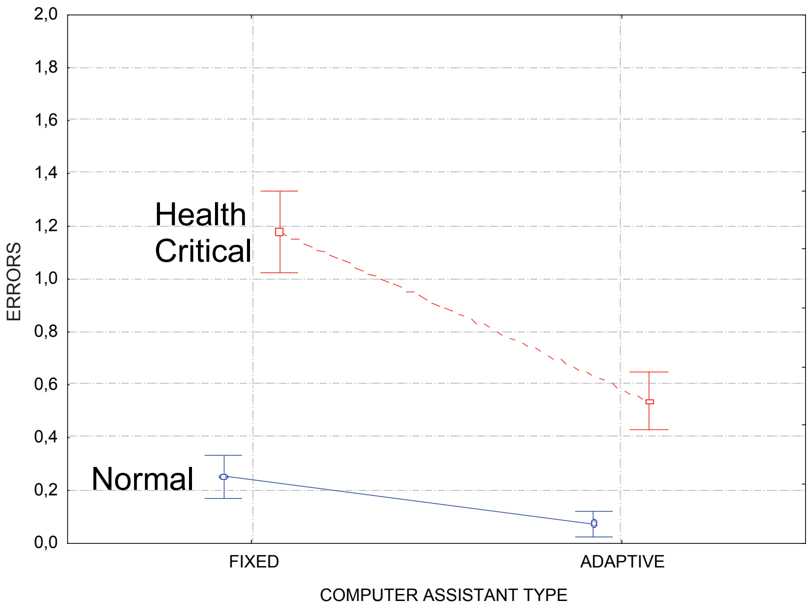
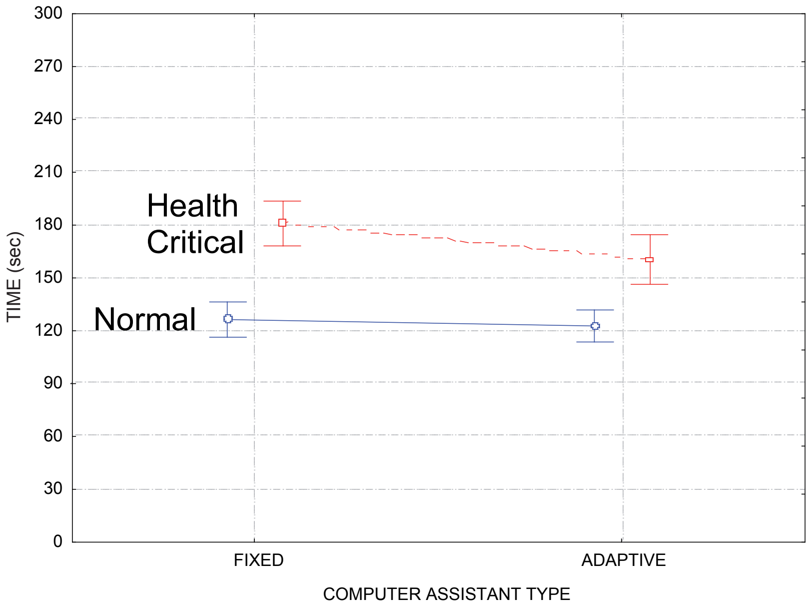


FIGURE 7.4

Mean time required, in seconds, with standard error bars, to complete scenarios in normal and health critical situations with a fixed and Adaptive Computer Assistant, $F(1,27)=5.24$, $p<.05$.



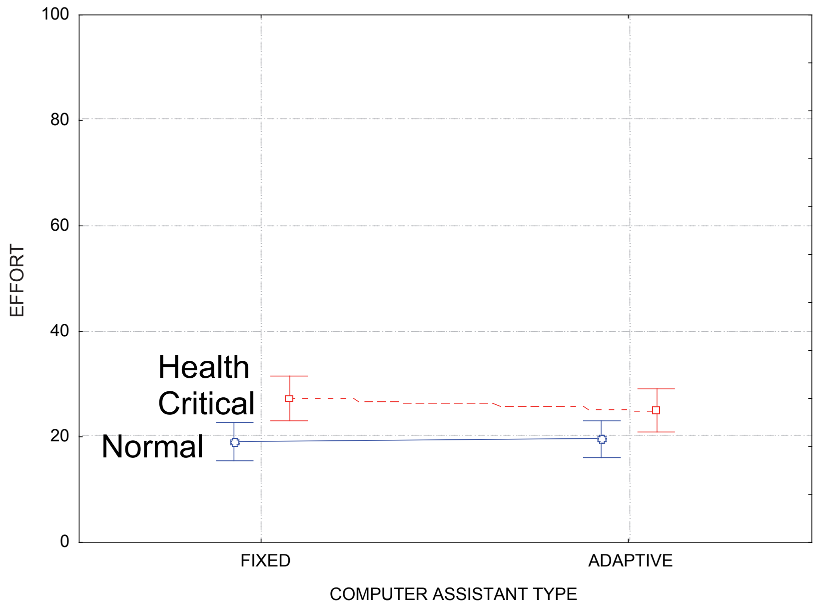


FIGURE 7.5

Mean rating of effort, with standard error bars, experienced while completing scenarios in normal and health critical situations with a fixed and Adaptive Computer Assistant

With respect to efficiency, Figure 7.4 shows that the adaptive assistant was more time efficient (*M*=141.22, *SE*=11.48), overall, than the fixed assistant (*M*=153.41, *SE*=11.91), $F(1,27)=5.24$, $p<.05$. Figure 7.5 depicts that effort did not differ across the two assistant types. However, the figure does show that overall effort was low.

To measure participant's satisfaction, we asked participants their preference for the type of assistant. Although 18 of the 28 participants (64%) indicated they preferred the adaptive assistant, this was not a statistically significant difference, $\chi^2(1)=2.30$, $p=.13$.

There was no difference in knowledge about diabetes after interacting with either the fixed or Adaptive Computer Assistant, $F(1,25)=.097$, $p=.76$. However, Table 7.3 shows that the participants performed, on a scale from 1 through 10, better on the second questionnaire than on the first. Thus, there was an increase in participants' knowledge $t(25)=-3.95$, $p<.001$.

TABLE 7.3

Means and standard deviation of diabetes knowledge questions answered correctly after 4 and 8 scenarios completed.

Questionnaire	Mean	Std. Deviation
Four scenarios	4.58	1.79
Eight scenarios	5.35	1.79

As listed in Table 7.4, results show that personal characteristics accounted for variance. Regarding effectiveness, gender, memory span, and perceptual speed accounted for 36% of the variance in number of errors made with the fixed assistant, $F(3,17)=4.16$, $p<.05$. Regarding efficiency, the variables vocabulary, locus of control, spatial ability, and gender accounted for 78% of the variance in time required to fulfill the scenarios with the Fixed Assistant, $F(6,14)=12.66$, $p<.001$. The predictors vocabulary, locus of control, memory, spatial ability, gender, and age accounted for 81% of the variance in time required to fulfill the scenarios with the Adaptive Assistant, $F(6,14)=14.73$, $p<.001$. In addition, vocabulary, age, locus of control and memory explained 34% variance in effort experienced with the Fixed Assistant, $F(4,18)=1.84$, $p<.05$. Age, locus of control, gender, and memory explained 54% variance in effort experienced with the Adaptive Assistant, $F(5,17)=5.56$, $p<.05$. Finally, concerning satisfaction, working memory, spatial ability, and age accounted for 43% of variation in preference for type of Computer Assistant, $F(3,17) =5.51$, $p<.001$.

TABLE 7.4

Multiple regression analyses of variances in self-care activities and outcomes explained by personal characteristics (*N*=23).

Variable	Explained variance by predictor variables	R^2 (%)	Regression equation
Errors made with Fixed Assistant	Gender (G)	25	Errors = 53.77 -0.55*G -0.27*MS -.017*PS
	Memory Span (MS)	8	
	Perceptual Speed (PS)	3	
		36	
Time required to complete scenarios with Fixed Assistant	Vocabulary (VOC)	48	Time = -2833.62 -0.61*VOC -0.48*LOC+0.28*G+ 0.27*SPAT
	Locus of Control (LOC)	25	
	Gender (G)	8	
	Spatial ability (SPAT)	1	
	Total	78	
Time required to complete scenarios with Adaptive Assistant	Vocabulary (VOC)	50	Time = 1945.85 -0.71*VOC -0.59*LOC +0.13*MS +0.42*SPAT +0.23*G -0.21*A -0.15*PS
	Locus of Control (LOC)	20	
	Memory Span (MS)	3	
	Spatial Ability (SPAT)	3	
	Gender (G)	3	
	Age (A)	1	
	Perceptual Speed (PS)	1	
	Total	81	
Effort experienced with Fixed Assistant	Vocabulary (VOC)	21	Effort = 375.39 -0.15*VOC -0.61*A -0.35*LOC -0.26*MS
	Age (A)	10	
	Locus of Control (LOC)	2	
	Memory Span (MS)	1	
		34	
Effort experienced with Adaptive Assistants	Age (A)	22	Effort = -583.42 -0.72*A -0.46*LOC +0.31&G -0.27*MS
	Locus of Control (LOC)	20	
	Gender (G)	6	
	Memory Span (MS)	6	
	Total	54	
Preference for Computer Assistant Type	Processing Speed (PS)	27	Preference = -2.48 -0.52*PS +0.31*SPAT +0.26*A
	Spatial Ability (SPAT)	12	
	Age (A)	4	
	Total	43	

As listed in Table 7.5, in relation to the improvements of the Digital Diabetes Diary, participants commented on two main issues, namely multimodality and mobility. In relationship to modality, participants suggested that they would like to see the information in multiple modalities. Thus, they liked the feedback not only in text, but also in graphs, images, sounds, and speech. In regard to mobility, participants suggested to have a version of the diary that runs on their PDA or mobile phone. This could alleviate the dependence on the home computer and facilitates more up to date and accurate logging of their daily food consumption. Other remarks were made about simplifying the diary entries and general usability issues, such as undoing errors and simplification of diary entries.

TABLE 7.5

Patients' suggestions for improvement of the Digital Diabetes Diary (*N*=23).

Statement type	Frequency	Example
Multimodality	7	Give better multimodal feedback on processes, for example, in a graph or chart. Also, provide ways to present your info to thirds, like the physician.
		I can imagine, you sometimes can't see optimally, so it would be beneficial if the assistant would talk to you and explain what to do.
		It would be good to have a more multimodal interaction with the assistant. This will give more information in one glimpse. It can help you get a better idea of your current health situation, be more aware of thresholds, and pick up patterns.
		Implement extra notifications, possible with audio support.
Mobile devices	7	When someone has a mental problem, the constant delivery of information is beneficial. Not only on the desktop computer but also outside the house.
		I want to get more information. Also when I'm outside and I get into problem, I would like to have an assistant.
		A PDA might be beneficial. It might be tricky first, but people learn. It would be easier to support self-care. People are not going to run into their house and you can always download it to your desktop
		I like to think I have something with me when something happens, that I can consult. A mobile version would be a nice.
General suggestion for improvement	8	My biggest problem was the understanding of the language. For example, one must know what nutrition belongs where in the food chain.
		Constrain the Yes/No and Finish buttons to prevent making mistakes.
		Put in some standard meals/snack that automatically will be divided in different ingredient in your diary.
		The assistant should be more supportive of errors. If an error has been made, the computer should make it possible to restore, solve the problem.

7.5 DESIGN AND EVALUATION OF A MULTIMODAL MOBILE DIET DIARY

In response to the suggestions made by the participants about improvements of the Digital Diabetes Diary, we designed a Mobile Diet Diary for the support of self-care and evaluated the effect of a multimodal interface on its usability (Bojic, Blanson Henkemans, Neerincx, Mast, & Lindenberg, 2009). As illustrated in Figure 7.6, users could fill in their personal information, including gender, age, date of birth and weight. Based on these data the diary calculated the Body Mass Index (BMI), and the daily advised amount of calories. In turn, as illustrated in Figure 7.7, users could enter their meals in their diary. After filling their diary (Figure 7.8), they received multimodal feedback from the diary in text, images and speech. The feedback discussed if they ate in accordance with the daily advised amount and on which aspect they could improve, e.g., calories, carbohydrates, fats and proteins.* A demo of the diet diary was presented at the Mobile HCI conference 2008 and was awarded, by the Mobile Experiences Awards, a silver medallion.

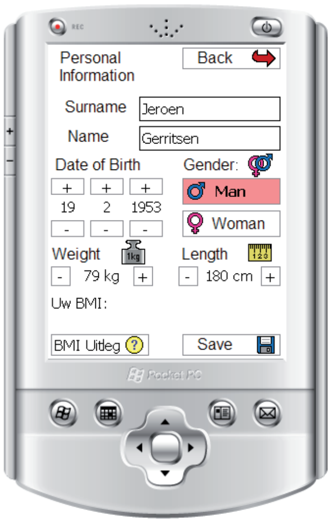


FIGURE 7.6

Entering Personal Infomation in Mobile Diet Dairy, including name, surname, gender, length, date of birth, weight and calculation of BMI in text and images.

* http://www.mvo.nl/voeding-en-gezondheid/download/Ri%2090%20496%20EEG.pdf

FIGURE 7.7

Entering meals in the Mobile Diet Diary with interface in text and text and images. Translated from Dutch to English.

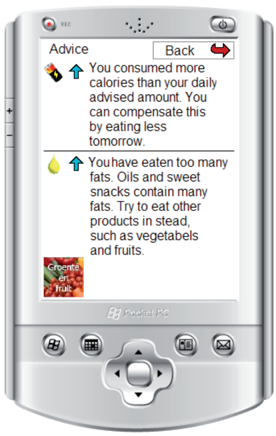


FIGURE 7.8

Feedback on the diary entry in accordance with the daily advised amount and on which aspect they could improve, e.g., calories, carbohydrates, fats and proteins.

The application was evaluated in TNO Experience Lab, with 32 healthy older adults. The experiment took place according to a within-subject design. Following the Scenario Based Design approach, participants completed tasks according to scenarios, which describe the daily life of an overweight older adult. Each participant completed four comparable scenarios under different feedback conditions and evaluated the diary's usability, i.e. effectiveness, efficiency, and satisfaction. The four feedback conditions were text (control measurement), text and images, text and speech, and text, images and speech. The order of conditions was counter balanced.

The study procedure took place as follows. First, we surveyed participants' demographics, cognitive abilities, and personality traits. Then, the participants received a short tutorial and an example scenario to familiarize them with the upcoming tasks. During the experiment, the participants were monitored through cameras and remote screen software, but were otherwise undisturbed during their completion of scenarios. Also, the user actions were logged by the application, measuring the number of actions, number of navigational errors and scenario time. After each scenario, the users filled in a NASA-TLX questionnaire, measuring workload, and answered a number of diet related questions relevant to the scenario, measuring health literacy. After completion of all scenarios, the users filled in a questionnaire that surveyed their satisfaction with the different multimodality conditions. They received a questionnaire asking to order the different conditions concerning preference, ease of use, clarity, and quickness of use from least to most preferred, scoring 1, 2, 3 or 4 points, accordingly.

Results showed that participants had significant preference for text and images in relation to solely text, $F(1,9)=9.76$, $p<.001$. However, as illustrated in Figure 7.9, when adding speech as modality (i.e., as second modality to text or as third modality to text and speech, this led to a decrease in preference, $F(1, 31)=8.91$, $p<.05$. Furthermore, as listed in Table 7.6, the combination of text and images was perceived as the easiest in use, $F(3, 104)=8.25$, $p<.001$, provided most clarity, $F(3, 104)=11.72$, $p<.001$, and quickest in use, $F(3, 104)=13.31$, $p<.001$. However, we did not find an effect of the different feedback modality combinations on effectiveness, and efficiency. Moreover, short term memory, $F(1,9)=6.52$, $p<.001$, and spatial ability, $F(1,9)=11.63$ with a $p<.001$, explained variance in the use in relation to efficiency of the Mobile Digital Diary.

FIGURE 7.9

Preference for feedback in Text (*M*=2.11, *SD*=1,14), Text and Speech (*M*=2.00, *SD*=0.72), Text and Images, (*M*=3.33, *SD*=0.74), and Text, Images and Speech (*M*=2.56, *SD*=1.25), F(1, 31)=8.91, p<.05.

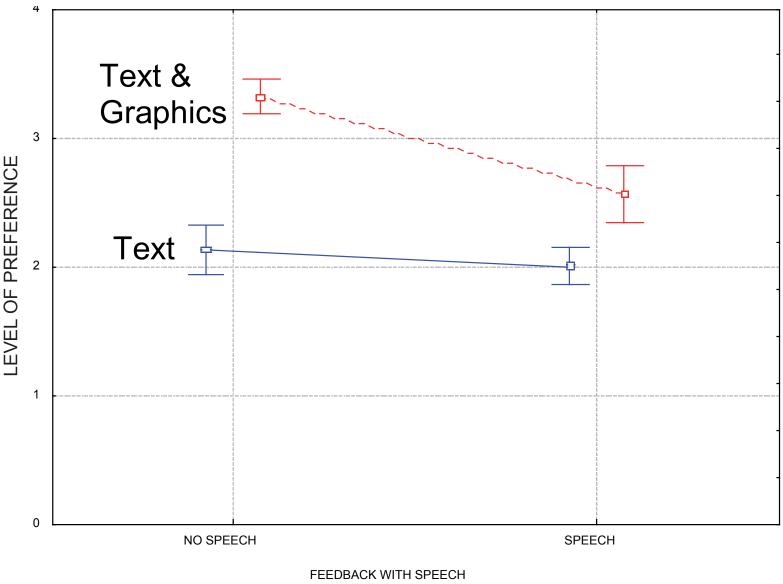


TABLE 7.6

Average Ease of use and clarity of different feedback modalities.

Usability Aspect	Text		Text & Speech		Text and images		Text, Images and Speech	
	Mean	Std.	Mean	Std.	Mean	Std.	Mean	Std.
Ease of use[1]	2.33	1.17	2.07	0.83	3.33	0.68	2.33	1.17
Clarity[2]	2.11	1.21	1.93	0.57	3.44	0.64	2.63	1.23
Quickness of use[3]	2.81	1.16	2.04	0.74	3.26	0.77	1.89	1.00

[1]F(3, 104)=8.25, p<.001

[2]F(3, 104)=11.72, p<.001

[3]F(3, 104)=13.31, p<.001

7.6 DISCUSSION

In this study, we evaluated an Adaptive Computer Assistant designed to supervise older diabetics' self-care, support limiting illness and acute treatment, and develop health literacy. The design of the assistant was based on domain, task and scenario analyses and was developed in collaboration with the Leiden University Medical Center (LUMC). Healthy older adults performed activities with the assistant according to scenarios that described the daily life of a diabetes type II patient with normal and health critical situations. We compared an adaptive assistant that adjusted its feedback to the participants' health situation with a fixed one.

In summary, the Adaptive Computer Assistant was more effective in dealing with normal and health critical situations than a fixed cooperative Assistant. Also, it led to more time efficiency. Overall, the participants experienced little effort performing the scenarios suggesting that the Digital Diary with Computer Assistant was easy to use. In addition, working with the user interface and receiving feedback from the assistant enhanced the participants' knowledge of diabetes care. However, there was no significant preference for the Adaptive Assistant. Furthermore, the fixed assistant did not lead to better knowledge of diabetes type II, but our assessment may not have been sensitive enough to detect learning differences.

From the closing interviews with participants at the end of the study, we assessed that there was an appeal for a mobile and multimodal version of the Digital Diabetes Diary. Based on these findings, we conducted a study on the use of a multimodal Mobile Diet Diary and evaluated it with older adults. Although this is not reflected in the effect of different modalities on effectiveness and the efficiency of the diary, results from the study showed that participants had significant preference for text and images above solely text. This could suggest that there is a preference for multimodality with the use of a mobile diary. However, when adding speech as modality, the preference decreased in relation to solely text and text and graphics. This actually shows that there is a general preference for text and graphics and designers should be careful when adding speech to mobile applications for older adults due to its possible negative effect on the interaction.

As we anticipated, there was a relationship between participants' personal characteristics and their use of and preference for the assistant. Men with higher memory span and perceptual speed tended to make fewer errors. Relatively younger men with a higher vocabulary and spatial ability and an external locus of control required less time to complete the scenarios with the

Fixed and Adaptive Assistant. Younger adults with a higher vocabulary and memory span and an external locus of control experienced less effort with the Fixed and Adaptive Computer Assistant. Finally, older adults with lower processing speed and spatial ability tended to prefer the Adaptive Computer Assistant. Also with the mobile diary, short term memory and spatial ability influenced the variance in the efficiency of the application.

Results of our study have implications for the design of eHealth technology. Integrating adaptivity in the design of Computer Assistants appears to increase effectiveness and time efficiency. The use of the assistant in general, led to a low level of experienced effort and an increase in health literacy regarding diabetes. Consequently, use of an Adaptive Assistant may enable older diabetics to integrate self-care activities in their daily life, thus maintaining quality of life, enhancing health literacy, and increasing adherence to medical treatment (Leventhal & Mora, 2005; Murray et al., 2004).

Users' personal characteristics, including age, gender, cognitive abilities and personality traits, influence users' evaluation of the Computer Assistants. From both the analysis and the open interview, we assessed that vocabulary plays an important role in performance variation. To address this issue, the diary could offer a thesaurus feature. To the users' liking, they can turn it on, which triggers tooltips that explain uncommon words. Also, people with an external locus of control spend less time on performing their tasks. This could entail that they rely on the external support of the Computer Assistant and not elaborate on the feedback internally. Consequently, the Computer Assistant supports health critical situations adequately, but in normal situations it could be beneficial, for example to prevent the out-of-the-loop problem, to involve the user more in the treatment process. This can be realized by giving more extensive explanation of the steps that took place and the reasoning behind it.

In conclusion, the use of an Adaptive Computer Assistant, which adjusts its feedback style to the patient, was effective and time efficient. The assistant has the potential to help older chronically ill patients cope with their self-care, including enhancing health literacy, and consequently increasing medical adherence. Moreover in accordance with previous research (Emery et al., 2002), our findings show that the use of text and graphic in a multimodal interface can contribute to the usability of mobile devices, whereas adding speech does not necessarily contribute to the satisfaction with the interaction. Moreover, personal characteristics, such as demographics, cognitive abilities and personality traits influence the evaluation of these devices. Thus, when developing eHealth services for home computers and mobile devices, multimodality and personal characteristics play an important role and must be considered in the design process. We address these issues in the next chapter, which covers the design of a Personal Computer Assistant for self-care adherence and evaluation, in the field, with overweight patients.

8

* Blanson Henkemans, O.A., Boog, P.J.M. van der, Lindenberg, J., Mast, C.A.P.G. van der, Neerincx, M.A., and Zwetsloot-Schonk, J.H.M. An Online Lifestyle Diary with a Persuasive Computer Assistant Providing Feedback on Self-Management. Special Issue Technology & Health Care "Smart environments: technology to support healthcare", In Press.

SUSTAINABLE SELF-CARE IN THE FIELD

The previous chapters discussed lab studies depicting that Personal Computer Assistants could be suitable for self-care, concerning troubleshooting of domestic medical instruments and increasing medical adherence. The current chapter discusses a randomized controlled trial (RCT) on assistants that support overweight persons to perform self-care independently, over an extended period of time. We designed a Persuasive Computer Assistant, which stimulated people to maintain a healthy lifestyle over a longer period of time, and evaluated its influence on self-management, i.e., the use of an Online Lifestyle Diary called DieetInzicht.nl. The assistant is represented by an animated iCat, which shows different facial expressions and provides cooperative feedback following principles from the motivational interviewing method. We conducted the RCT with 118 overweight people over a period of four weeks and studied the difference between diary use with and without Computer Assistant feedback.

Results show that the Computer Assistant contributed to filling in the diary more frequently, reduced the decline in motivation to perform self-management, lowered the (reported) Body Mass Index (BMI), and improved the ease of use. Furthermore, diary use increased knowledge of maintaining a healthy lifestyle. Finally, personal characteristics, i.e., locus of control, vocabulary, computer experience, age, gender, education level and initial BMI, explained the variance in the diary use and its outcome. Of the 118 participants 35 filled in the closing survey, covering motivation, BMI, lifestyle knowledge and ease of use, which implies that the findings based on these results are mainly representative for motivated participants. In general, this study shows that the DieetInzicht eHealth service, including a personal Computer Assistant, is likely to support motivated overweight people and lifestyle related diseases to get a better insight in and adhere to their self-care over a longer period of time. This chapter is based on a previously published article.*

8.1 INTRODUCTION

8.1.1 *Overweight*

As discussed in the literature and supported in Chapter 6, eHealth with Personal Computer Assistants can potentially stimulate self-care adherence (Ahern, Kreslake, & Phalen, 2006; Larizza et al., 2006; Nooijer et al., 2005; Tufano & Karras, 2005). Amongst others, eHealth could support overweight people maintaining a healthy lifestyle and reduce their weight, (Dulmen et al., 2007; Haynes et al., 2005; Leventhal et al., 2008; Maes & Karoly, 2005). Globally, 1 billion people are classified as being overweight (World Health Organization, 2003b). In the Netherlands, it impacts approximately 45% of the population. Moreover, obesity affects approximately 9% of the population (Statistics Netherlands (CBS), 2007b). Besides causing personal distress (Blaine, Rodman, & Newman, 2007; Jeurissen & Spanje, 2001), being overweight may lead to an increase in the number of patients with lifestyle related and chronic diseases, such as diabetes and cardiovascular diseases (Kreijl & Knaap, 2004; Statistics Netherlands (CBS), 2007a).

8.1.2. *Persuasive Assistants*

In a study on eHealth with personalized support of rheumatoid arthritis (Berg et al., 2007), patients received internet-mediated physical activity intervention with personal counseling. Home-based patients had access to the website, called Cybertrainer, for one year. Results show that this intervention was more effective with respect to the total amount of physical activity than a similar program without additional facilities.

Previous chapters discuss the influence of personalized computer assistance on patient self-care and eHealth, concerning feedback and appearance. In regard to feedback, the assistant applied a cooperative feedback style, i.e., it has a coaching character, explains and educates the patient, and expects high participation of the user. Or it applied a directive feedback style, i.e., it has an instructing character with brief reporting and expects low participation of the user. Results showed that the cooperative assistant was more effective and satisfactory, whereas the directive assistant was more efficient. In regard to appearance, the use of animated personas and robots can stimulate and improve the quality of the interaction (Krahmer, Ruttkay, Swerts, & Wesselink, 2002). For example, research on the use of a robot for the support of diabetes treatment according to scenarios showed that people preferred interacting with a social intelligent animated iCat over a simple text interface (Looije et al., 2006; Looije, Neerincx, & Cnossen, 2009). These studies took place in smart home laboratories with healthy adults.

Although the studies described above have shown the value of eHealth technology and personal computer assistance, there is little prolonged research on how the use of a personal Computer Assistant can improve diet and exercise behavior of people who are overweight. Consequently, the key question of this chapter reads:

How can a Persuasive Computer Assistant, applying motivational cooperative feedback through an animated avatar support Online Lifestyle Diary use over a prolonged period of time?

To answer our research question, this chapter discusses the implementation of a Persuasive Computer Assistant in the Online Lifestyle Diary DieetInzicht.nl. Subsequently, it discusses the influence of the Computer Assistant on the self-care process, i.e., the use of the diary, and outcomes, i.e., motivation, weight and health literacy. This will take place according to a randomized control trial with adults, who are overweight, at home.

8.2 ONLINE LIFESTYLE DIARY WITH PERSUASIVE COMPUTER ASSISTANT

8.2.1 *User Interface*

Following research on self-care, eHealth technology and personalized computer assistance, we designed a Persuasive Computer Assistant and integrated it in an existing PHP and MySQL based Lifestyle Diary called DieetInzicht (www.dieetinzicht.nl). The goal of the diary is help users obtaining better insights on how to maintain a healthy lifestyle without external manipulation. It provides insight in how to maintain a healthy lifestyle by offering objective information in relation to diet and physical activity.

The study enrolment and diary use proceeded as follows. After carefully reading the instruction on the homepage and signing an online form of consent, the participants create a personal account with username and password. With the username and password, they log in and access personal, diet, exercise, report, and product pages. On the personal page, participants manage their personal data, i.e., weight and password. Moreover, they set their personal self-care goals, regarding diary use, diet and exercise. Examples of goals are, respectively, “Fill in diary four times a week”, “Eat a healthy amount of fat”, and “Exercise lightly on a daily basis”. As illustrated in Figure 8.1, in the diet page they keep a diary of the amount of products they consumed. They specify the product, category, e.g., vegetable or meat, quantity and moment. In the activity page, they keep a diary of the exercise performed. They specify the time, category, e.g., intense or lightly intense, and moment of day. In the report page, they receive a report on nutrition components consumed, including, calories, fats, proteins, and carbohydrates, and number of calories burned during their activities. Finally, on the product page, they browse for products and accompanying nutrition facts.

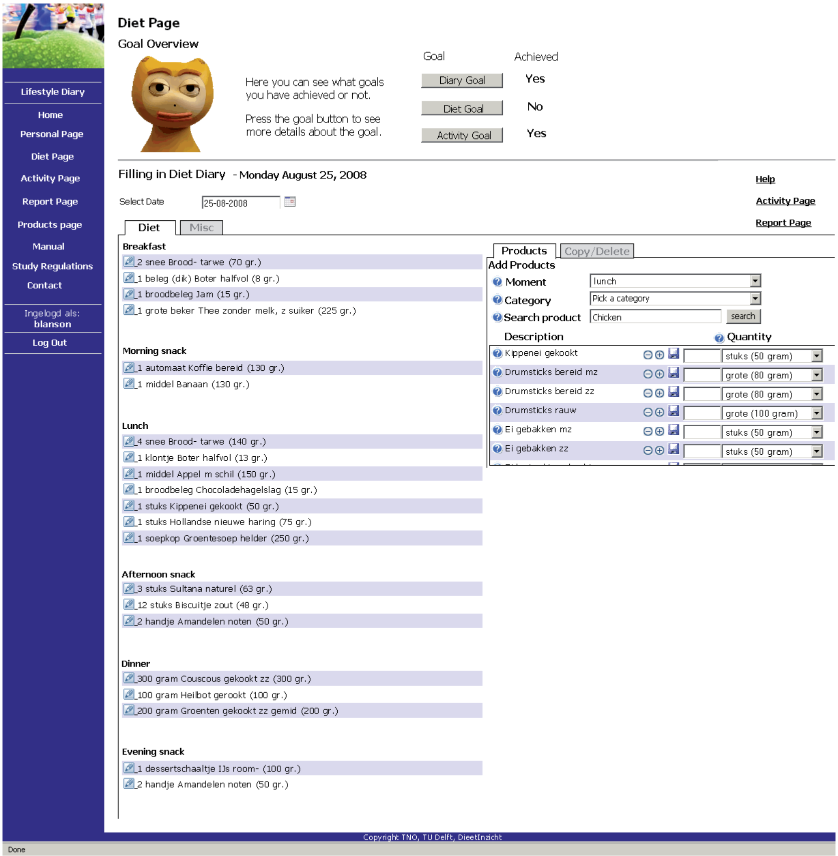


FIGURE 8.1

Diet page of Online Lifestyle Diary with Persuasive Computer Assistant.

8.2.2 *Persuasive Computer Assistant*

The Persuasive Computer Assistant was implemented in the DieetInzicht website. As illustrated in Figure 8.1, it was situated at the top of each page. The Assistant is persuasive in the sense that it offers support by monitoring the diary and providing cooperative feedback, which is coaching and aims at patient engagement. Participants are free to pick goals, which are important to them. In turn, the assistant indicates if the participant is fulfilling his or her goal or not. Also, it will give suggestions on how to achieve goals in the future by referring to relevant pages on the website of the Voedingscentrum, the Dutch association for nutrition.

When giving feedback, the Computer Assistant follows principles of the motivational interviewing method (Miller & Rollnick, 1991). Research has shown that the application of motivational interviewing, which focuses on social functioning, discussing problems and giving feedback in the form of advice and direction, is an effective therapeutic approach (Santa Ana et al., 2008). The Computer Assistant does not have the full range of motivational interviewing abilities of a human caregiver. However, we applied some principles of this method in our Computer Assistant that previously were well-appreciated by the users of the SuperAssist iCat, a robotic assistant for diabetics (Looije et al., 2006; Looije et al., 2009) and the HealthBuddy, a telemonitoring system for patients with heart failure (Vrijhoef et al., 2008). In accordance with the motivational interviewing principles, the Computer Assistants:

- **Expresses empathy: The assistant is mindful that the participant might have other priorities ("You were not successful in achieving your goal for today. Maybe you have been busy.");**
- **Is cheering and complimenting: The assistant congratulates the participants when goals are achieved ("Well done! You are successful in achieving today's goal.");**
- **Explores discrepancies between life style goal and current lifestyle: To give a good overview of the situation, the assistant indicates what goals are not realized and suggests how this could be improved ("You were not successful in achieving your goal for today. Too bad. But do not get discouraged and try again tomorrow.");**
- **Supports self-efficacy and optimism: The assistant stays optimistic about achieving goals and underlines that it is acceptable to make errors and the participant has the ability to realize goals ("You were not successful in achieving your goal for today. This is not terrible. It will go with small steps, so keep trying the coming days.").**

Both the personal lifestyle goals and the feedback were evaluated and improved where necessary by an independent dietician from Leiden University Medical Center (LUMC).

To illustrate the functioning of the Computer Assistant, Table 8.1 lists the diary components according to the control system model (Carver & Scheier, 2002). In brief, the PHP website is connected to a MySQL database, which contains the users' personal details, personal goals, and entries in food and activity diary. The database also contains descriptions and dependencies of all personal goals (4 for each category, i.e., diary, diet and exercise) and a list with related textual and graphical feedback. When accessed, the website runs the MySQL queries to check if the user is achieving his or her goals or not. Depending if the query outcome is positive or negative, the website shows the related textual feedback accompanying iCat animations.

TABLE 8.1

Control system model (Carver & Scheier, 2002) and diary components.

Control system model components	Description	Diary components	Computer Assistant activity
Input function	Perception of current situation	MySQL database with users and their diary entries	Assess participant's food and exercise diary entries
Reference value	Standard, set point, or goal	MySQL database with users' lifestyle goals	Retrieve participant's diary, diet, and exercise goals
Comparator	Device that makes comparisons between input and references value	Computer Assistant model of comparison between goals and diary entries based on MySQL queries	Based on diary entries, test if goals of each category is fulfilled or not.
Output function	Error corrective behavior	MySQL database with Computer Assistant feedback based on comparison	Based on the test results, select feedback text array, pick relevant texts from feedback list list, and select the happy or sad iCat animation.

As illustrated in Figure 8.2, the assistant is represented by an animated iCat, which shows three facial expressions: neutral, happy and sad. Research has shown that these facial expressions can contribute to the understanding of the Computer Assistant (Bakhuysen, Krahmer, & Swerts, 2005). Moreover, it can enrich the experience of empathy by the assistant (Looije et al., 2006; Looije et al., 2009). In our study, when opening the website, the assistant looks neutral, i.e., blinks its eyes, occasionally looks around. When the user addresses its goals, by clicking on the relevant goal button, the assistant will elaborate on the goal, as described earlier, and will look happy when successful or sad when not. The iCat is a research platform created by Phillips for studying human-robot interaction. It is a plastic yellow cat with a face and a body, which expresses emotions by moving its lips, eyebrows, eyes, eyelids, head and body (Breemen, Yan, & Meerbeek, 2005).

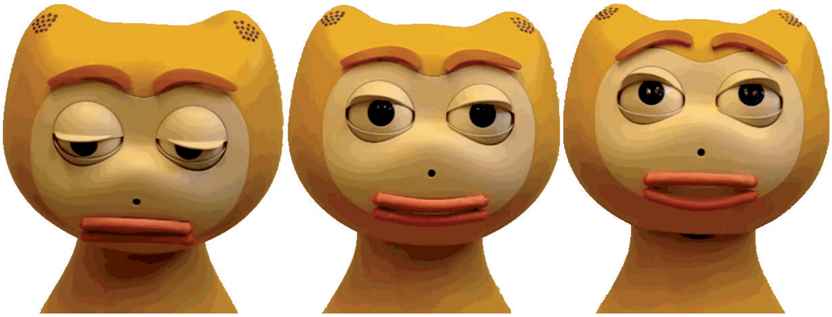


FIGURE 8.2

Examples of happy, neutral and sad facial expressions of the Persuasive Computer Assistant in accordance with feedback.

During our study, we will evaluate if a Persuasive Computer Assistant can increase the adherence to an Online Lifestyle Diary for overweight adults in relation to frequency, completeness, motivation and health outcomes over a prolonged period of time. Based on our findings in previous chapters and recent studies on eHealth technology, we expect that participants receiving persuasive feedback from the Computer Assistant will use the diary more adequately, better fulfill lifestyle goals, be more motivated (Alpay et al., 2007), and develop more self-managing knowledge (Morrow et al., 2006). Also, we expect that active use of the diary will lead to improved self-care outcomes (Fogg, 2003), such as optimizing the Body Mass Index (BMI). Finally, we expect that personal characteristics, i.e., demographics, cognitive abilities and personality traits, will influence the use of the diary (Czaja et al., 2006). To validate our hypotheses, we conducted a randomized control trial (RCT). Overweight adults used an online diary from their home computer for a period of four weeks. With this method we expect obtaining valid empirical findings for the benefits of eHealth technology (Ball et al., 2002; Higgins & Green, 2008).

8.3 METHOD

Over a period of three months, we recruited 191 Dutch adults who are overweight (BMI between 25 and 30 kg/m²), but who had no previous experience with the DieetInzicht website and were not under periodic treatment with a specialist at a hospital. People are considered healthy when they have a BMI between 18.5 and 25 kg/m² and are considered overweight when they have a BMI between 25 and 30 kg/m². A BMI above 30 kg/m² is considered obese. They were recruited through the Dutch Research Institute for Applied Science (TNO) participants database with overweight people and an advertorial in an online Dutch national newspaper, which ran for one week. Of the 191 participants, 118 participants filled their diary for at least 5 days and were included in the study. As listed in Table 8.2, the final sample consisted of 21 male and 97 female participants, between the age of 21 and 65 (*M*=43.24, *SD*=11.55). The average BMI was 27.90 (*SD*=2.42) and 65 participants had a Computer Assistant. Furthermore, 35 participants completed all surveys. Participation was voluntarily. There was no communicative stimulus or financial compensation, but among the participants that fulfilled the study, 5 prizes, worth 150 Euro each, were administered, chosen by lottery. Lastly, the study protocol was approved by the Dutch Medical Ethical Testing Commission (METOPP).

	Recruited and assigned to condition	**Maintained diary >5 days (male/female)**	**Completed all surveys (male/female)**
Computer assistant	97	65 (15/50)	18 (3/15)
No Computer Assistant	94	53 (6/47)	17 (3/14)
Total	191	118 (21/97)	35 (6/29)

TABLE 8.2

Frequency table of male and female participants with and without Computer Assistant.

Following the RCT, the diary autonomously assigned the participants, double blinded, to the study group or control group. The study group set lifestyle goals, filled in the diary and received feedback from the Computer Assistant. The control group performed the same activities, but did not have a Computer Assistant providing feedback, i.e., the Computer Assistant was deactivated in the diary. To assess the influence of the Computer Assistant, we measured diary use, concerning the number of days people used the diary and the number of days between the first and last day of use, and the average number of products and physical activities entered per day. Furthermore, we studied adherence to lifestyle goals, motivation, health literacy, BMI, and usability. Finally, we studied the influence of personal characteristics on the use of the diary.

As listed in Table 8.3, participants started the study with completing an online survey concerning demographics, Body Mass Index (BMI) and computer experience. Also, they completed a survey on self-care motivation (Williams, 1998). This survey addresses the expectation to be able to use the diary and maintain a healthy lifestyle. Furthermore, they completed the locus of control scale test, which measures if people have a predominantly internal locus of control, i.e., attribute events to their own control, or external locus of control, i.e., attribute events to external circumstances (Rotter, 1954). Finally, they completed a vocabulary test (Dutch translation of Shipley Institute of Living Scale (Shipley, 1986)), and lifestyle knowledge test, which was supervised by the LUMC dietician.

TABLE 8.3

Surveys issued and number of participants that completed the specific surveys.

Survey	**Pre-study (Day 01)**	**Study (Day 01–28)**	**Exit survey (Day 28)**
Demographics	118		
Computer Experience	118		
Locus of Control Scale	118		
Vocabulary	118		
Lifestyle knowledge	118		35
Motivation	118	50 (on Day 14)	35
BMI			35
Daily diet and physical activities		118	
Online diary evaluation			35

The first three days after signing in, participants were free to explore the website and adjust the goals. Then, participants received an email instructing to choose three lifestyle goals, one each for the diary, diet and physical activity, for the remainder of the study. On day 14, participants received an email referring to the survey on self-care motivation. On day 28, participants received an email referring to the closing online survey. It assessed self-care motivation, lifestyle knowledge, Body Mass Index, and evaluation of the diary, concerning the diary's contribution to a healthy lifestyle and its usability. The usability survey consisted of questions answered on a 7 point Likert scale questions about the contribution of the diary to maintaining a healthy lifestyle, ease of use, relevance, trust, and educational value. Finally, the participants received a debriefing document.

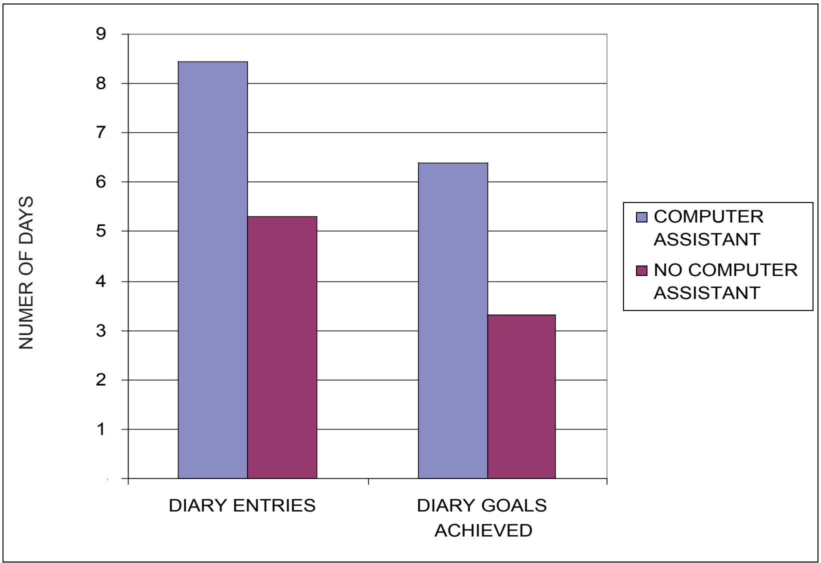
To evaluate the influence of the Computer Assistant on the self-management process, we performed a t-test for independent variables. To evaluate the influence of the Computer Assistant on the self-management outcomes, concerning health literacy, motivation, and BMI differences across the four week period, we performed a repeated measure ANOVA. To determine whether personal characteristics explain variance in the use of the diary and its outcome, we conducted a multiple regression analysis with six predictors whereby we assume linearity, random sampling, no perfect collinearity between the independent variables, and independence. The predictors were age, BMI, education level, computer experience, vocabulary, and locus of control.

8.4 RESULTS

In regard to diary use, as illustrated in Figure 8.3, participants who had the Computer Assistant, filled in their diary with higher frequency. Of the 28 days, they filled in their diary more often (M=8.43, SD=9.11), than when having no Computer Assistant (M=5.30, SD=7.12), $t(116)=3.04$, $p<.05$. Moreover, participants with Computer Assistant filled in their diary over a longer range of days, with a maximum of 28, (M=9.70, SD=9.44) then people without a Computer Assistant (M=6.51, SD=7.73), $t(116)=1.98$, $p<.05$. Results did not show a significant influence of the Computer Assistant on completeness, i.e., the average amount of distinct food products and activities people entered in their diary per day (M=12.62, SD=6.56).

FIGURE 8.3

Mean frequency of diary entries (*M*=8.43, *SD*=9.11 and *M*=5.30, *SD*=7.12), (t(116)=3.04, p<.05) and diary goals (*M*=6.38, *SD*=8.96 and *M*=3.30, *SD*=5.88), t(116)=2.15, p<.05) achieved, in days, with and without Computer Assistant (*N*=118)



Following the frequency of diary use, also illustrated in Figure 8.3, participants with a Computer Assistant achieved their daily diary goals more often, i.e., more days (*M*=6.38, *SD*=8.96), than participants without a Computer Assistant (*M*=3.30, *SD*=5.88), t(116)=2.15, p<.05. Results did not show a significant influence of the Computer Assistant on adherence to diet, i.e., the number of days they achieved their diet goals (*M*=.86, *SD*=2.48) and exercise, i.e., the number of days they achieved their exercise goals (*M*=.63, *SD*=3.59).

At the beginning, halfway through and at the end of the study, we surveyed the participants' self-management motivation, concerning keeping a diary and maintaining a healthy lifestyle. Participants' score ranged from 1, not motivated at all, to 7, very motivated. The number of participants, who filled in the survey halfway through and at the end decreased and we are confronted with a considerable amount of missing values. Consequently, we solely analyzed the 35 participants (18 with and 17 without Computer Assistant) who completed all three surveys with a Kruskal-Wallis ANOVA. As displayed in Figure. 8.4, participants' self-reported motivation to fill in the diary declined over the period of four weeks, t(65)=4.75), p<.001. However, the participants with Computer Assistant declined less than the participant without a

Computer Assistant, H(1,32)=4.47, p<.05. As displayed in Figure. 8.5, participants' self-reported motivation to perform self-management declined over the period of four weeks, t(63)=1.91, p<.05. In contrast, the participants with Computer Assistant increased their motivation, H(1,32)=5.56, p<.05.

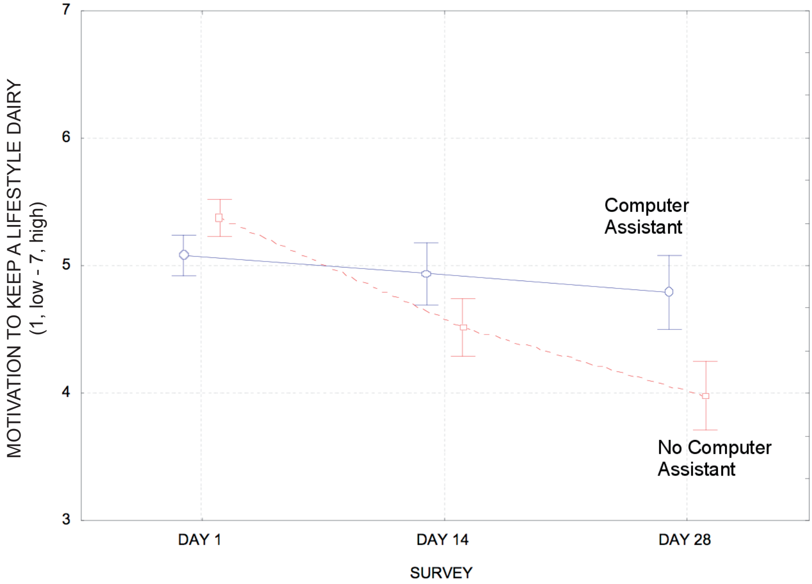


FIGURE 8.4

Mean score for motivation to keep a diary (1, low – 7, high), at the beginning (*M*=5.38, *SD*=.59 and *M*=5.00, *SD*=.53), halfway through (*M*=4.75, *SD*=.66 and *M*=4.93, *SD*=.68), and end of the study (*M*=4.84, *SD*=.96 and *M*=4.07, *SD*=.94), with and without Computer Assistant (*M*=4.84, *SD*=.96 and *M*=4.07, *SD*=.94) (*N*=35), with an interaction effect, H(1,32)=4.47, p<.05.

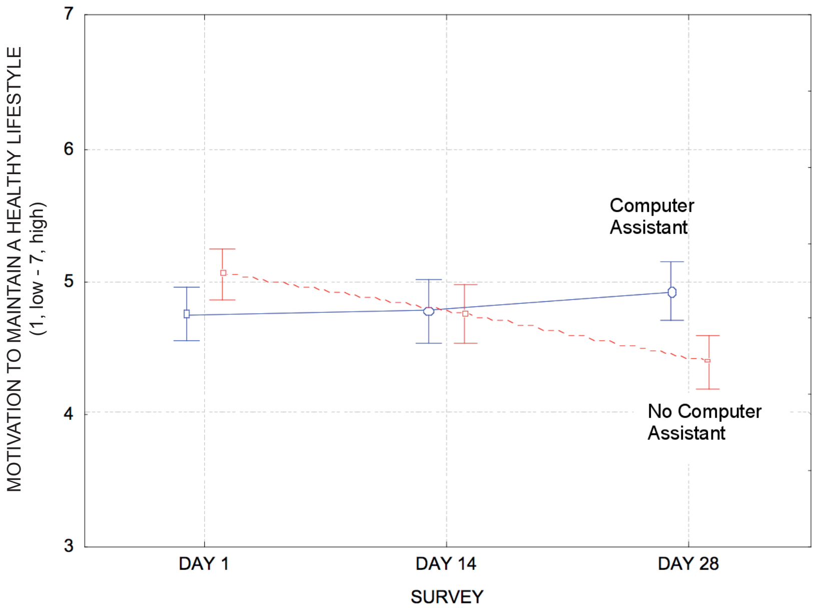


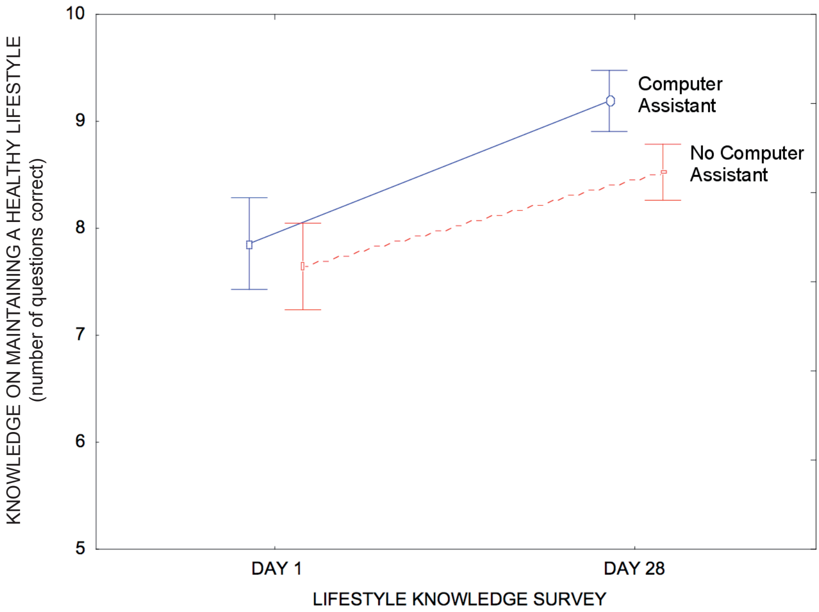
FIGURE 8.5

Mean score for motivation to maintain healthy lifestyle (1, low – 7, high) at the beginning (*M*=4.66, *SD*=.87 and *M*=5.03, *SD*=.84), halfway through (*M*=4.73, *SD*=1.13 and *M*=4.68, *SD*=1.02), and end of the study (*M*=4.82, *SD*=.78 and *M*=4.15, *SD*=.86), with and without Computer Assistant (*M*=4.82, *SD*=.78 and *M*=4.15, *SD*=.86) (*N*=35), with an interaction effect, H(1,32)=5.56, p<.05.

At the beginning and end of the study, participants completed surveys on knowledge of maintaining a healthy lifestyle. As illustrated in Figure 8.6, the 35 participants who filled in both surveys, scored better at the end (*M*=8.84, *SD*=1.11), than at the beginning of the study (*M*=7.63, *SD*=1.58), F(1, 30)=50.81, p<.001. There was no difference between participants' score with and without Computer Assistant.

FIGURE 8.6

Mean score for knowledge of maintaining a healthy lifestyle at the beginning and end of the study, with and without Computer Assistant (*N*=35), F(1, 30)=50.81, p<.001.



Considering the 35 participants who entered their BMI at the beginning and end of the study, people with a Computer Assistant scored an average BMI of 28.39 (*SD*=2.32) at the beginning of the study and an average of 27.78 (*SD*=2.32) at the end. People without a Computer Assistant scored, on average, a BMI of 28.23 (*SD*=2.36) at the beginning of the study and 28.16 (*SD*=2.49) at the end. As displayed in Figure 8.7, people working with the diary reportedly lowered their BMI significantly. Moreover, people with the Computer Assistant decreased their BMI even more, F(1,28)=13.84, p<.001.

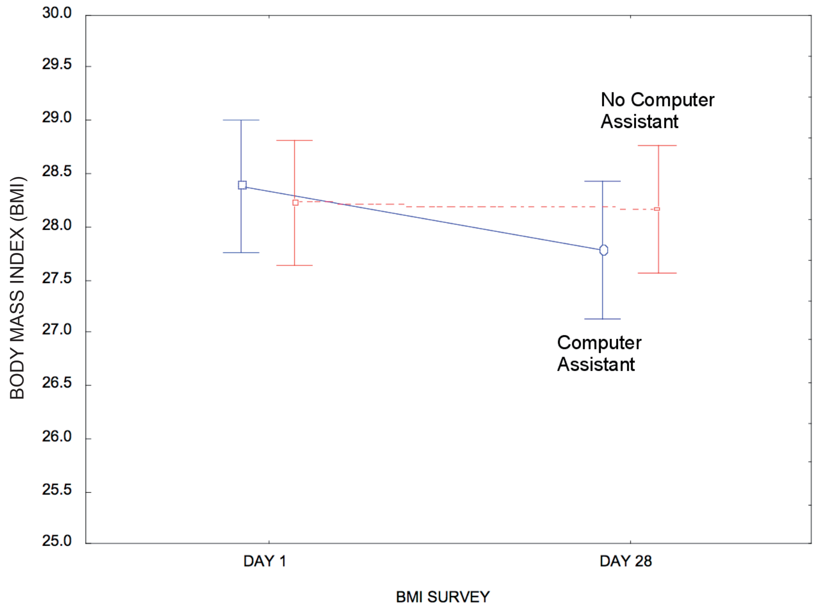


FIGURE 8.7

Mean Body Mass Index at the beginning (M=28.39, SD=2.32 and M=28.23, SD=2.36) and end of the study (M=27.78, SD=2.32 and M=28.16, SD=2.49), with and without Computer Assistant (N=35), with an interaction effect, $F(1,28)=13.84$, $p<.001$.

At the end of the study, participants evaluated the diary's usability. As listed in Table 8.4, on a scale from 1 (high) through 7 (low), 35 participants, 18 with and 17 without Computer Assistant, rated its contribution to maintaining a healthy lifestyle, ease of use, relevance, trust and educational value. In addition, we analyzed the influence of the Computer Assistant on these aspects. As displayed in Figure 8.8, results of a Mann-Whitney test, show that participants with Computer Assistant appraised the diary as easier to use (M=4.89, SD=1.32), then participants without a Computer Assistant (M=3.94, SD=1.30), $Z(34)=2.27$, $p<.05$.

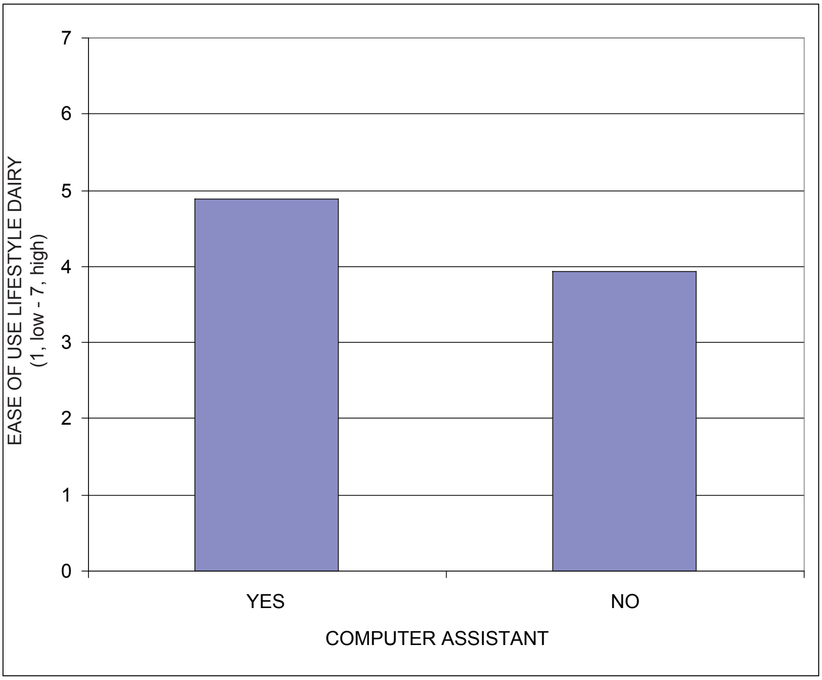
Usability aspect	Mean (SD) with CA	Mean (SD) without CA	p-value
Easy of use	4.89 (1.32)	3.94 (1.30)	0.03
Relevance	3.63 (1.42)	3.82 (0.73)	0.95
Trustworthiness	4.67 (0.90)	4.00 (1.06)	0.08
Educational value	4.43 (1.39)	4.24 (1.39)	0.57
Contribution healthy lifestyle	4.06 (0.25)	3.59 (1.35)	0.22

TABLE 8.4

Evaluation of diary usability with and without Computer Assistant (CA) (1 low – 7 high) (N=35).

FIGURE 8.8

Mean rating of diary's usability aspect "Ease of use" (1 low – 7 high), with (*M*=4.89, *SD*=1.32) and without Computer Assistant (*M*=3.94, *SD*=1.30), (*N*=35), Z(34)=2.27, p<.05.



As listed in Table 8.5, results of the multiple regression analysis explain the variance in diary use and outcomes by personal characteristics. Concerning diary use, Locus of Control, BMI, vocabulary, computer experience, and lifestyle knowledge explain 23% of the variance in diary use completeness, $F(5,111)=6.52$, $p<.001$. For the 35 participants, who filled in all the questionnaires, concerning diary use outcomes, BMI, computer experience, and age explained 37% of the variance in self-reported motivation to maintain a healthy lifestyle halfway the study, $F(3,21)=4.95$, $p<.05$, and 21% at the end of the study, $F(2,22)=3.75$, $p<.05$.

TABLE 8.5

Multiple regression analysis of variance in Online Lifestyle Diary completeness, motivation and usability explained by personal characteristics (*N*=118).

Variable	Explained variance by predictor variables	R^2 (%)	Regression equation
Average diary entries in per day	Locus of control (LOC)	10	Completeness = -16.92
	BMI	5	+ 0.31*LOC + 0.24*BMI
	Vocabulary (VOC)	4	+ 0.20*VOC – 0.14*CE
	Computer Experience (CE)	2	+0.12*LK
	Lifestyle Knowledge (LK)	2	
	Total	23	
Motivation to maintain a healthy lifestyle, beginning of study	BMI	11	Motivation = 5.90 –
	Vocabulary (VOC)	7	0.40*BMI – 0.44*VOC
	Computer Experience (CE)	15	+0.44*CE
	Total	33	
Motivation to maintain a healthy lifestyle, halfway of study	Computer Experience (CE)	21	Motivation = -39.11
	Age	5	- 0.45*CE +0.25*Age –
	Education Level (EL)	5	0.23*EL
	Total	29	
Motivation to maintain a healthy lifestyle, end of study	Computer Experience (CE)	16	Motivation = 4.65 - 0.40*CE
	Education Level (EL)	4	+ 0.19*EL
	Total	20	

8.5 DISCUSSION

In a randomized controlled trial (RCT), we evaluated the influence of a Persuasive Computer Assistant on the adherence to an Online Lifestyle Diary for self-management. In the diary, overweight adults created a personal account, set lifestyle goals, kept track of dietary and physical activities, and received a report of consumed nutritional products and burned calories. The assistant is represented by an animated iCat, which shows different facial expressions and provides cooperative feedback on the diary entries following the motivational interviewing concept. We studied the influence of the assistant on the use of the diary, achieving lifestyle goals, self-management motivation, health literacy, BMI, and usability.

Results of our study show that adding the Persuasive Computer Assistant contributed to using the diary and achieving diary goals more frequently, reduced the decline in motivation to perform self-management, lowered the participants' BMI, and increased the diary's ease of use. Furthermore, the use of the diary increased the participants' knowledge of maintaining a healthy lifestyle. These findings are in accordance with earlier presumed benefits of eHealth (Nooijer et al., 2005). Overall, the diary was evaluated as usable; moreover, the computer assistance contributed positively to the diary's ease of use. Finally, personal characteristics explained the variance in completeness of diary use and self-reported ability to perform self-management.

These findings have implications for designing eHealth services. The use of a Computer Assistant, represented by an avatar, which provides cooperative feedback, applies motivational interviewing and accompanies the feedback with facial expression, can contribute to self-management adherence. It can support overweight people to keep a diary more adequately and fulfill personal lifestyle goals, stay motivated over time, lower their BMI, and increase knowledge on how to maintain a healthy diet and perform exercise. Consequently, in accordance with existing research, our findings show that people adhering to self-care, which is stimulated by our assistant, can improve their health condition and maintain it in the long run (Maes & Karoly, 2005). Lastly, when designing eHealth, we must consider the influence of personal characteristics, such as age, education level, computer experience, locus of control and vocabulary on the use of technology. More specifically, participants who had a high internal locus of control, and scored high on vocabulary, computer experience, entered the diary more completely and younger participants, who scored higher on computer experience and education level, were more motivated to maintain a healthy lifestyle.

When interpreting these results, we must consider three important issues. First, of the 191 recruited participants, only 118 fulfilled our requirement of using the diary for at least 5 days. This has implications for our findings. Mainly, we see that, in line with the literature (Kaplan & Litewka, 2008), it is difficult to stimulate people to maintain a healthy lifestyle through eHealth over a longer period of time. This is especially the case when, like in our study, the experiment leader had no personal contact with the participants and people learn about the Online Lifestyle Diary through an advertisement or mailing and create an account independently and anonymously. However, the initial goal of the diary is to obtain insights in how to maintain a health lifestyle. Possibly, after using the diary a number of days, the users feel they achieved this goal and thus feel less compelled to continue entering their food and activities in the diary. Consequently, it could be beneficial to add features to the diary to make it more attractive to use it continuously. Examples of features are a recall function, which reminds the user of the diary, an information library with interesting news on diet and exercise, and a community service that facilitates communication with peers. Also, it is difficult to guarantee the accuracy of diary entries and survey of demographics and physical measures, such as BMI. Consequently, to assess the exact influence of the use of the diary on health condition requires ongoing clinical testing.

Second, relatively few men participated in the study. Existing research suggests two possible causes. A study shows that women are more socially-orientated and men more individually-orientated (Eckel & Grossman, 1998). As a result, women would be more willing to participate in our voluntary study than men. In addition, in the past decennia, women increased their dissatisfaction with their body shape. Also, women are more likely to judge themselves overweight than men (Cash, Morrow, Hrabosky, & Perry, 2004). In accordance with these theories, men would be less likely to see the importance of the Online Lifestyle Diary.

Third, of the 118 eligible participants, only 35 completed all surveys, which assess influence of the Computer Assistant on self-management motivation, health literacy, BMI, and usability. This entails a bias in the closing survey outcomes, i.e., the Computer Assistant leads to better diary use outcomes amongst the most motivated participants, which makes the effect of the assistant on less motivated people arguable. Still, there are arguments that the findings are representative for the whole population. Namely, the Computer Assistant increased adherence to the diary amongst all eligible participants and, in the group that completed all surveys, the number of participants with and without Computer Assistant was equally divided.

In conclusion, the Persuasive Computer Assistant contributes to the adhering to the usable Online Lifestyle Diary by overweight adults. Participants with assistant used the diary more frequently, achieved diary goals more regularly. Moreover, motivated participants with assistant stayed more motivated, and lowered their BMI. Finally, the use of the diary contributed to lifestyle knowledge. Consequently, this eHealth technology is likely to support people with lifestyle related and chronic diseases, such as diabetes and cardiovascular diseases, to adhere to their self-care. This includes maintaining a healthy diet and regularly performing physical activities. Finally, personal characteristics influence the use of the online diary and its outcomes and need to be taken into consideration when designing eHealth technology.

9

GENERAL CONCLUSIONS AND DISCUSSION

Chronic and lifestyle related diseases form a global concern. For example, diabetes affects 171 million and over1 billion people world wide are overweight (World Health Organization, 2003b). To accommodate this increase in care demand, there is a gradual shift from the individual patient receiving one-sided treatment from the health care system towards a more independent, self-determining patient, who engages in self-care activities. To realize this shift, the patient needs to be provided with relevant medical information and support for developing self-care skills, including use of medical instruments and adhering to self-care objectives (Lorig & Holman, 2003) and Personal Computer Assistants could support this.

Our initial problem statement was that there is little empirical research on how the support for self-care for a variety of patients, with different care needs in different situations, should be offered and what its effect is. Our goal was to design and evaluate the effect of the different Personal Computer Assistant features, i.e., feedback style and appearance, on self-care process and outcomes in smart home environments and the field. Our main research question read:

Which Personal Computer Assistant features can enhance eHealth services and support self-care, in relation to troubleshooting of domestic medical instruments and adherence to self-care objectives?

Our findings answer this question positively by showing that Personal Computer Assistants contribute to the use of eHealth services and self-care by guiding daily health-related activities and support troubleshooting activities in critical situations.

This contribution is realized by monitoring the patient environment and medical record and tuning the Personal Computer Assistant's features, i.e., feedback style and appearance, to the user, context, tools, and self-care activity. Moreover, the design of the assistants needs to address the explaining value of Human Factors on the variation in self-care performance and outcomes with the use of eHealth services. Consequently, eHealth with Personal Computer Assistants effectuates personalization, which contributes self-care processes and outcomes in relation to troubleshooting of domestic medical instruments and adherence to self-care objectives. Specifically, a Computer Assistant providing feedback in a cooperative style leads to more effective and satisfying performance of self-care activities, whereas a directive feedback style facilitates more efficient and vigorous performance. Moreover, an adaptive assistant that switches from cooperative to directive in critical situations is more effective, efficient and satisfying in regard to acute self-care treatment and health literacy. Finally, a Persuasive Computer Assistant contributes to adhering to self-care goals and, accordingly, to positive outcomes such as motivation preservation and a healthy Body Mass Index (BMI).

9.1 SUMMARY OF RESULTS

9.1.1 *Design of Personal Computer Assistants*

Chapter 1 discusses two feedback styles. The first style is cooperative, which has a more coaching, explanatory and educational character, and aims at user involvement. The second style is directive, which has a more instructing and reporting character, and aims at user compliance. In our research we further refined and augmented these feedback styles and, in turn, the initial Design Specifications.

As summarized in Table 9.1, the two feedback styles have their advantages and disadvantages. With the cooperative feedback style, the user learns competencies, develops understanding, and the user and assistant complement each other, which leads to better performance long-term. Paradoxically, when the user becomes more experienced in self-care, this style can become tedious and patronizing. With the directive feedback style, the user needs few competencies, there is better short-term performance, and it facilitates vigorous acting. However, due to the low involvement level, the user is prone to making errors when called upon and loses the idea of control. The latter is called the out-of-the-loop performance problem (Endsley & Kiris, 1995). To combine the advantages of both feedback styles, we incorporated them both in one Computer Assistant. In turn, the assistant could adjust its feedback style to the context, i.e., normal and health critical situations, which led to more effective, efficient and satisfying self-care.

Finally, performing self-care has a vital importance for patients; however, quality of life, the patient's ability to enjoy normal life activities has equal importance, but can conflict with self-care. For example, a patient might want to perform exercise regularly, but not at the cost of his social life. This trade-off creates a motivational issue and to support people to improve their lifestyle long-term, we designed a Persuasive Computer Assistant. It supports combining self-care activities and maintaining a good quality of life by provides cooperative feedback to personal lifestyle goals according the motivational interviewing method in combination with an animated avatar.

Computer Assistant	**Description**	**Design rationale**
Cooperative feedback	Assistant has a coaching character, aims at explaining, informing, and educating the user, and expects high participation of the user. Feedback is provided in text and images.	Contributes to user satisfaction and development of self-care abilities.
Directive feedback	Assistant has more of an instructing character, aims at brief reporting, and expects low participation of the user. Feedback is provided in text and images.	Contributes to vigorous and efficient problem solving in cases of anomalies.
Adaptive Computer Assistant	Assistant initially provides cooperative feedback, but in case of health critical situations, switches to directive feedback. Feedback is provided in text and images.	Contributes development of self-care skills, but has the ability to switch to more efficient support when necessary, i.e., taxing of cognitive resources.

TABLE 9.1

Different Computer Assistants types varying in feedback style and appearance.

TABLE 9.1

Different Computer Assistants types varying in feedback style and appearance (continued).

Computer Assistant	Description	Design rationale
Persuasive Computer Assistant	Assistant provides cooperative feedback, according to a motivational interviewing process, and increases effectiveness and satisfaction. Feedback is provided in text and images by an animated avatar, which uses its nonverbal communication, e.g., facial expression, to underline the feedback.	Focuses on empathetic support and positive user experience, which stimulates pursuing long-term personal self-care goals.

In regard to Personal Computer Assistant's appearance, we defined three interaction modalities. These were text, images and speech. The text condition entails that the information in presented in plain text. The images condition implies that the information is presented in consistently used images and icons. The speech condition implies that the information is spoken in clear native tongue. In accordance with the literature (Fisk et al., 2004), the text font is at least 12 points and not overly complex or decorative, images are of sufficient size and of high contrast, and speech had a low frequency.

9.1.2 *Effect on Self-Care Performance and Outcome*

First, results show that developing and implementing Personal Computer Assistants (PCAs) was technically feasible (Chapter 3). Moreover, in combination with an eHealth service, such as an Online Lifestyle Diary, they fulfilled our initial Design Specifications. These cover the requirement of tuning medical information to the patient's activities, i.e., searching, retrieving, sharing, and managing medical data and information.

Second, results showed that different types of PCAs contribute to self-care in relation to troubleshooting of domestic medical instruments and self-care. Interestingly, as listed in Table 9.2, the cooperative and directive feedback concepts apply for both troubleshooting of domestic medical instruments and for adhering to self-care objectives. The cooperative feedback leads to more effective and satisfying solutions for technical problems, i.e., most malfunctions solved and most preferred, and more satisfying performance of troubleshooting, i.e., most preferred. The directive feedback style leads to more efficient troubleshooting and addressing health critical situation (Chapter 4). This also comes apparent during remote joint troubleshooting and in case of health critical situations. Support for remote joint troubleshooting is most usable, i.e., most malfunctions solved and most satisfying, when an older novice patient receives cooperative feedback, but an expert younger technician receives directive feedback (Chapter 5). Support for health critical situations, such as a hypo- or hyperglycemic attack, is most usable, i.e., most anormalities solved, in least time and highest satisfaction, when the Computer Assistant is adaptive, i.e., switch from cooperative to directive feedback in health critical situations (Chapter 7).

Moreover, to stimulate overweight people to perform self-care activities long term, the Persuasive Computer Assistant showed to be successful. As discussed, medical adherence is a considerable bottleneck and this assistant stimulates users to adhere to self-care objectives, i.e., using an Online Lifestyle Diary. In turn, patients stayed motivated, decreased their BMI and developed health literacy (Chapter 6 and Chapter 8).

TABLE 9.2

Influence of eHealth with Personal Computer Assistants on troubleshooting of domestic medical instruments and self-care adherence.

Self-care aspect	Result
Troubleshooting of domestic medical instruments	The use of a PCA, combined with a Troubleshooting Environment, contributed to troubleshooting and maintenance. Moreover, the cooperative feedback was more effective and satisfying, whereas the directive feedback was more efficient (Chapter 4). When a novice older patient and a remote younger technical specialist, each with a PCA, jointly troubleshoot domestic medical instruments, the process is optimal when the patient receives cooperative and the technical specialists receives directive feedback (Chapter 5).
Self-care adherence	In relation to performing daily care activities, people strongly preferred receiving cooperative feedback from their PCA, which involves them highly in setting and executing the care plan (Chapter 6). An Adaptive Computer Assistant, which adjusts its feedback style to the patient's situation, was more effective in dealing with normal and health critical situations, and, generally, led to more time efficiency (Chapter 7). When a Computer Assistant is offered on a multimodal mobile diary, older adults prefer feedback in text and images. Concerning effectiveness and efficiency, it is most beneficial if users can pick the modality combination of choice (Chapter 7). A Persuasive Computer Assistant monitors personal goals and provides cooperative feedback through an animated avatar, with different facial expressions, following the motivational interviewing concept, contributed to self-care adherence. It stimulated overweight people to adhere to an Online Lifestyle Diary, reduced the decline in motivation, lowered their (self-reported) BMI, and improved the ease of use (Chapter 8). The use of an Online Lifestyle Diary in which people enter their daily meals, physical exercise and medication was generally experienced as usable and led to an increase in health literacy (Chapter 8).

Finally, our exploration of Human Factors in Human-Computer Assistant Interaction, showed hat personal characteristics related to demographics, cognitive abilities and personality traits explained variance in the evaluation of the eHealth services with Personal Computer Assistants. In relation to moderating troubleshooting process and outcome, effectiveness was positively influenced by computer experience and education level; efficiency was positively influenced by spatial ability and age, and preference for cooperative assistant was positively influenced by education level, spatial ability and age. This could imply that older users with lower education and computer experience struggle more with Computer Assistant support for troubleshooting medical instruments and could be helped by more intensive support that aims at coaching, explaining, informing, and educating the user, in a complementing manner.

In relation to adhering to self-care objectives process and outcome, effectiveness was positively influenced by vocabulary; efficiency was positively influenced by age, vocabulary and internal locus of control; preference for Adaptive Computer Assistant was negatively influenced by processing speed and spatial ability; motivation to maintaining a healthy lifestyle was positively influenced by initial weight, and younger age. This could imply that older users with a smaller vocabulary and who attribute life experiences to external factors, struggle with computer assistance for adhering to self-care objectives.

9.2 ANSWER TO RESEARCH QUESTION

9.2.1 *Tune Feedback and Appearance to the User and Self-Care Activities*

The results showed that, to contribute to eHealth services, Personal Computer Assistants (PCA) must facilitate tuning its features, concerning different feedback styles and appearances, to the user. In relation to feedback style, a cooperative feedback style, which is coaching, educating, and expects high participation of the user, leads to more effective and satisfying troubleshooting.

However, a directive feedback style, which is instructing and reporting and expects compliance of the user is more time efficient. As a result, when an older patient and a remote technical specialist jointly solve technical problems, with the use of a troubleshooting application, it is optimal when the patient has cooperative and technical specialist has directive feedback. In regard to adhering to self-care objectives, people who used an Online Lifestyle Diary, which was monitored by their PCA, equally preferred the cooperative feedback. Because adherence is most likely in case of high satisfaction, this is the preferred style. Still, when attending to occasional health critical situation, an Adaptive Computer Assistant, which switches to a directive feedback style in case of a health critical situation, is most effective, satisfactory, and contributes to health literacy. To assess a health critical situation, a monitoring system plays an important role. Thus, the assistant should not be solely dependent of the input of the user, but also be connected to a monitoring system, in the user's environment, for example in the rooms and fridge, through which it can detect abnormal behavior, for example irregular movement or consumption.

The PCAs appearance needs to be similarly adjusted to the user's situation. We expected that in case of critical situations, time or health wise, it is more beneficial when information is presented in an unambiguous manner and with clear illustration that bring across complex concepts. This would mostly be realized by text and images (Emery et al., 2002). Also, we expected that for long term satisfying experience to stimulate adherence, it would more beneficial to have interaction through an animated assistant that supports the textual interaction with facial experiences (Gloyd, 2003). However, our findings show that, when using a mobile eHealth service, such as a mobile diet dairy, people preferred text and graphics but did not necessarily like to have vocal feedback. Thus, instead of presenting the Computer Assistant in a predetermined appearance, it could be more beneficial if the eHealth service facilitates the user to adjust the Computer Assistants' appearance to his or her likings and learn and interact according his or her preference over time.

Finally, we found that Human Factors, including demographics, cognitive abilities, and personality traits, explain variance in the influence of PCAs on self-care processes and outcomes. People with a lower educational level, smaller vocabulary, less computer experience, or external locus of control experience more challenges with self-care activities. Moreover, with older adults, personal characteristics, such as education level, spatial ability and computer experience, play a more predominately role in the variance in performance of self-care activities, such as the solving of technical problems that occur with medical instruments. As a result, they need compensating computer assistance that empathizes with the user, explains concepts step by step of complex processes, such as troubleshooting, develops self-efficacy, goal setting and intrinsic motivation and leads to self-coping.

These findings depict a number of interesting explanations of variance in the participants' evaluation of the posed eHealth with Computer Assistants, which are also in line with the literature (Carroll, 1993; Christensen & Smith, 1995; Czaja et al., 2006; Fisk et al., 2004; Kneckt, 2000; O'Hea et al., 2005). These can give direction to ho to attend to the different user characteristics for the support of self-care. However, we need to consider that the power across the different regression analyses was relatively low. Illustratively, approximately 27 people participated per lab experiment and 120 people participated in our field study. This implies that our findings have more an explorative character, than that it gives a decisive answer on how Personal Computer Assistants need to be designed to meet with each individual user's personal characteristics. In conclusion, we need to continuously and iteratively involve the future user in the design process when developing supporting services with Personal Computer Assistants.

9.2.2 *Personal Computer Assistant Contributes to Self-Care Activities*

When successfully attending to the user as described in previous paragraph, applying PCAs in eHealth services positively contributes to self-care processes and outcomes. It contributes to the effectiveness, efficacy, and satisfaction of troubleshooting technical problems that occur with domestic medical instruments, both individually and in remote collaboration. Specifically, it contributes to representing the problem, diagnosis and fault isolation, exploring the problem space, generating hypotheses, gathering information, hypothesis evaluation and decision making, selecting, implementing and evaluating solution options, and adding experience to personal experience library (Jonassen et al., 2003). In turn, the user will solve more technical problems with less effort, in less time, and with more satisfaction.

Moreover, attending to user's personal goals stimulates people to adherence to their self-care objectives. With setting personal goals, logging self-care activities and receiving cooperative feedback according the motivational interviewing concept, patients are more likely to adhere to different types of self-care objectives. These includes regulation, i.e., routine health maintenance; prevention, i.e., exercising, dieting, and self-examination; reaction, i.e., self-initiated responses to self assessed symptoms; and restoration, i.e., compliance to a professionally prescribed medication regimen (Leventhal et al., 2004).

9.3 IMPLICATIONS AND RECOMMENDATIONS

9.3.1 *Personal Computer Assistants for Patient Self-Care*

The results show a positive effect of Personal Computer Assistant with different feedback styles and appearance on the challenges with self-care activities. Adhering to self-care objectives, including the use of medical instrument, is a complex issue and dependent on the patient's knowledge, understanding, motivation, which can change per day, and the trade-off between maintaining a healthy life and a quality of life. The evaluation of the different Computer Assistants demonstrate that they support these self-care issues by offering support, which is cooperative when aiming at effective and satisfying performance, which is relevant for older patients, directive when aiming at efficient and vigorous performance, which is relevant for experts, adaptive when aiming dynamic support, which is relevant for attending to changing health situations, or persuasive support when aiming at motivation, which is relevant for sustainable performance.

In addition, results entail a number of social and scientific implications. Socially, the use of Personal Computer Assistants (PCAs) can help patients develop health literacy, regain self-efficacy and increase participation in society, which in turn will stimulate sustainable self-care performance and improve their long-term health (Welschen, 2008). As illustrated in the SuperAssist model in Figure 1.1, by monitoring the patient, offering tailored support, and mediating communication with remote specialist, PCAS contribute to a positive user experience and improve use of eHealth services. Illustratively, patients receive support for performing self-care, both preventively, e.g., maintain a healthy diet, exercise regularly and develop health literacy, and reactively, e.g., take medication and use medical instruments (Leventhal et al., 2004). Also, they can call upon the help of remote medical and technical specialists, who supervise the patients' well-being and the functioning of their domestic medical instruments, respectively.

The use of PCAS can help alleviate the pressure on the health care service. As discussed by Tsiknakis and Kouroubali, it can facilitate a fit between the involved actors, the performed activities and the used technology, which is required for the adoption and adequate use of eHealth services (Tsiknakis & Kouroubalia, 2008). By tailoring the support to the patient, it contributes to increase health literacy by offering relevant health information and support the prevention of illness and stimulate patient empowerment and, consequently, decreases the care demand (Wijler et al., 2008; Wise, Han, Shaw, McTavish, & Gustafson, 2008).

Scientifically, our findings have implications for different aspects of the Human-Computer Interaction. Lustria and colleagues reviewed thirty computer-tailored behavioral interventions and studied how they could be optimized for self-guided health interventions delivered via the Web, such as enhancing nutrition, diet and exercise (Lustria, Cortese, Noar, & Glueckauf, 2008). They found that further development of computer assistance for self-care requires empirically based guidelines for tailoring across populations, health services, health behaviors, and situations. Our approach and findings meet adequately with this requirement, which can be applied for further scaling up to more elaborate eHealth systems.

In relation to the use of domestic medical instruments, Karter and colleagues discuss that more frequent self-monitoring of blood glucose levels contributes to clinically and statistically better glucose level management (Karter et al., 2001). In accordance, to support adequate use of these instruments and taking our findings related to troubleshooting medical instruments into consideration, personalized support for the use of domestic medical instruments, such as glucometers and blood pressure meters are necessary. Our result shows that this support can be offered by the use of PCAs.

As discussed in Chapter 8, the use of an eHealth service, such as an Online Lifestyle Diary, with Computer Assistant contributed to self-care activities, but needed to be further enhanced to stimulate ongoing use. Based on our findings, enhancement can take place as illustrated in the following case. One of the aspects of the diary was the burden on the user of filling the large amount different food products and unit, and being connected to the home computer. A feature that could help shortening the entry time smart monitoring of the diary entries over time with pattern recognition. With this knowledge, the Computer Assistant recognizes patterns and provides the user with list of diary entries with which the user solely needs to concur. Another feature to simplify diary entries is scanning products with your mobile phone camera and storing them in the phone's database which, later on, can be synchronized with the diary on the home computer. This addresses the time burden and the dependency of the home computer. Moreover, it will increase the accuracy of the diary entries, because people will not need to memorize all the products consumed over the day.

9.3.2 *Design of Personal Computer Assistants for Self-Care*

In regards to the development process, the Cognitive Engineering (CE) approach proved fitting for testing HCI theories in practice. Through conducting Domain Analysis and setting Design Specifications, it enables iterative prototyping and evolution of innovative technology. In turn, its outcomes led to refining and augmenting the initial specifications. Moreover, it facilitated addressing issues related to medical ethics in patients' study participation. This could be achieved by the use of scenarios to help participants empathize with future users and by conducting studies in Smart Home Labs with healthy adults and, subsequently, in the field with actual patients. With this approach of continuously updating the framework of essential requirements throughout the prototyping, development, implementation, and use process, we can work towards broadly usable eHealth services (Dumay, 2007).

When looking at the CE process, we should also consider the influence of Design Specifications, distilled from practical technology use, on the current practice in the Work Domain (Hollnagel & Woods, 2005). Illustratively, our findings show that besides the functional aspect of Human-Computer Assistant interaction, i.e., optimizing the effectiveness and efficiency of task performance, there is also an interpersonal aspect. The interpersonal aspect focuses on optimizing the general satisfaction in task performance and is concerned with issues such as satisfaction and viability, i.e., the capacity to continue working together. Prendinger & Ishizuka argued that the use of social dimension and affective computing, i.e., the system's ability to recognize and reciprocate the human affective state, in animated agents can contribute to more enjoyable and ongoing interaction (Ishizuka & Prendinger, 2004; Picard, Vyzas, & Healey, 2001). The proposed Personal Computer Assistance shows how this interpersonal Human-Computer Interaction can be enabled, namely, by monitoring the user and adapting the feedback style and appearance to dynamic situations.

Accordingly, our application of Cognitive Engineering facilitates User-Centered Design (UCD), i.e., the development driven by the total user experience. In line with requirements posed in previous research on UCD, when developing innovative technology, such as eHealth services, CE supports iteratively gathering user requirements and applying them for tailored design. In our exploration of the effects of Human Factors on variation in eHealth use, demographics, personality traits and cognitive abilities play an important role in its use and outcomes. Consequently, they are essential factors in successful interaction between user and technology and thus the design and evaluation process of the user interface. This applies especially when using persuasive technology, which aims at changing attitudes and behaviors. Users must have a good experience, i.e., their requirements are met, to accept and follow computer feedback. Only when the eHealth services attend to the involved users, as described in this thesis, including both patients and medical specialists, the technology will be able to enhance the current self-care movement (Nijland, van Gemert-Pijnen, Boer, Steehouder, & Seydel, 2008).

9.3.3 *Personal Computer Assistants for Complex Task Environments*

An aspect we have not addressed in the SuperAssist Model is the provision of Personal Computer Assistants for medical professionals, such as physicians, dieticians and internists. Computer Assistants for their complex care tasks could contribute to the overall support and safety of the health care service. For example, an activity recognition system, which infers user activities based on the self-organization of surrounding objects that the user may manipulate to enhance remote monitoring and communication, can make the specialists work more efficient (Osmani, Balasubramaniam, & Botvich, 2008). In turn, this can enable them to address those patients who need supplementary human support.

Furthermore, our findings can contribute to the support of professionals in other domains that deal with complex tasks environment, i.e., with different actors with different needs in various situations, such as the naval, space and police domain. This is in line with our findings, discussed in Table 9.1, where cooperative feedback contributes to user satisfaction and development of abilities, directive feedback contributes to efficient problem solving, adaptive assistant contributes to dynamic situations, and persuasive assistant contributes to empathetic support and sustainable goal pursuing. For example, supervising officers on the bridge of a marine ship deal with low or high activity and complexity situations where multiple tasks with different level of acuteness need to be addressed simultaneous (Grootjen et al., 2006). An adaptive system interface could switch its feedback style from more coaching to directing depending on the level of workload experienced and offer it in different modality based on the complexity of the task.

Astronauts navigating on Mars are burdened with the life threatening impact of technical problems that occur with their equipment. Moreover, they are highly dependent on remote communication with the home base (Smets, Brake, Neerincx, & Lindenberg, 2008). As a result, it is essential that the supporting system facilitates effective and trustworthy interaction between astronaut and system. This can be realized by deploying persuasive virtual assistants that monitor the astronaut's health readings and the "health" of equipment. If a critical situation arises, the assistant can troubleshoot the technical problem, assess the astronaut's emotional state, and provide reassuring but effective guidance, e.g., resolve failure, go back to base, or set up communication link with nearby colleague.

Police officers on patrol and supervising criminality dense neighborhoods require specific information at specific time and place (Streefkerk et al., 2007). With the use of a Computer Assistant on their mobile devices, the officers can get context and subject relevant information. Based on the type of activity the assistant will provide its information in a convenient modality. For example, when monitoring street activities, information is provided in speech to enable the officer to visually survey the surrounding. When executing a surprise charge, the assistant gives an auditive notification, but provides information in text and images when convenient for the officer.

9.3.4 *Recommendations*

In addition to implications, the results bring about a number of recommendations in relation to future research of eHealth with PCAs for the improvement of self-care:

- **Continuously apply the User-Centered Design method extended with the Cognitive Engineering approach;**
- **Further explore the variance of personal characteristics in the use of eHealth services with Personal Computer Assistants for self-care with larger samples of participants;**
- **In a next design and evaluation cycle, assess the influence of eHealth with PCAs on clinical outcomes. However, regularly returning to the Smart Home Lab setting will help reinstating the user requirements;**
- **Use eHealth services with PCAs not as a replacement, but as an augmentation of the current health service. As discussed in Chapter 8, Persuasive Computer Assistants can support motivated patients to perform self-care, which facilitates medical specialists to reallocate their attention to patients who struggle more. This may imply that the medical specialists need to rethink their role and their tasks;**
- **Apply a multidisciplinary approach, which involves, among others, engineers, designers, medical specialists, psychologists, sociologists, and user representatives. This will enhance the chances that the development**

of PCAs fulfill the design specifications in the work domain;

- **Collaborate with manufactures of existing eHealth services. Their experiences can contribute to fluent integration of the PCAs in their applications;**
- **Pay attention to privacy and safety issues. As indicated in our feasibility study, in Chapter 3, it is necessary to focus on the privacy of the user information and data stored and used for personalized assistance.**
- **Explore current research projects on eHealth services. Sharing knowledge amongst different research institutes, the industry and applying it in the field can provide an empirical foundation for the use of eHealth. For example, LUMC, TNO and DieetInzicht, have ongoing plans with the use of Personal Computer Assistants for personalizing and contextualizing existing eHealth services and improve the user experience.**

In conclusion, the use of Personal Computer Assistants (PCAs), as applied in the SuperAssist project, in the eHealth setting is feasible and stimulates self-care activities. Prerequisite is that the PCAs attend its feedback and appearance to the user characteristics. In return, it can prevent patient related diseases, increase patient engagement in the care process, and decrease the care demand. Moreover, it can facilitate care givers to address those patients who need extra human attention.

With the help of his Personal Computer Assistant, John can adequately deal with his diabetes type II. He performs self-care activities, such as maintaining a healthy diet and exercising regularly, while maintain a good quality of life. In combination with keeping a Digital Diary, he receives personalized support for integrating his activities in daily life and for using domestic medical instruments. The Assistant is aware of John's personal characteristics and its feedback style and presentation are tuned to his current task and context. Through experience and receiving relevant information, he develops his health literacy and keeps his motivation. As a result, he rarely relapses into his old habits. In addition, during the remote communication with the technical and medical specialist, mediated by the Assistant, John can better explain his problems. Also, he can effectively and efficiently interpret and execute their instructions. This leaves more time for focusing on his work and spending quality time with his family.

REFERENCES

Ahern, D. K. (2007). Challenges and Opportunities of eHealth Research. *American journal of preventive medicine., 32*(5), S75.

Ahern, D. K., Kreslake, J. M., & Phalen, J. M. (2006). What is eHealth (6): perspectives on the evolution of eHealth research. *Journal of medical Internet research, 8*(1).

Alpay, L. L., Overberg, R. I., & Zwetsloot-Schonk, J. H. M. (2007). Empowering citizens in assessing health related websites: a driving force for healthcare governance. *International Journal of Healthcare Technology and Management (IJHTM), Special issue: "Governing ICT in healthcare and governing healthcare with ICT", 8*(1/2), 141-190.

Alpay, L. L., Toussaint, P. J., Ezendam, N. P. M., Rövekamp, T. A. J. M., Graafmans, W. C., & Westendorp, R. G. J. (2004). Easing Internet access of health information for elderly users. *Health Informatics Journal, 10*(3), 185-194.

American Diabetes Association. (2004). *A field guide to type 2 diabetes : the essential resource from the diabetes experts*. Alexandria, VA: American Diabetes Association.

Amichai-Hamburger, Y., Fine, A., & Goldstein, A. (2004). The impact of Internet interactivity and need for closure on consumer preference. *Computers in Human Behavior, 20*(1), 103-117.

Andrus, M. R., & Roth, M. T. (2002). Health Literacy: A Review. *Pharmacotherapy, 22*(3), 282-302.

Ashayeri, J., Teelen, A., & Selen, W. (1996). A production and maintenance planning model for the process industry. *International journal of production research., 34*(12), 3311.

Axton, T. R., Doverspike, D., Park, S. R., & Barrett, G. V. (1997). A model of the information processing and cognitive ability requirements for mechanical troubleshooting. *International Journals of Cognitive Ergonomics, 1*(3), 245-266.

Baan, C. A., & Poos, M. J. J. C. (2005). *Hoe vaak komt diabetes mellitus voor en hoeveel mensen sterven eraan?* Bilthoven: RIVM.

Bailey, B. P., Konstan, J. A., & Carlis, J. V. (2001). *The effects of interruptions on task performance, annoyance, and anxiety in the user interface.* Paper presented at the INTERACT2001, Tokyo, Japan.

Baker, D. W. (2006). PERSPECTIVE: The Meaning and the Measure of Health Literacy. *Journal of General Internal Medicine, 21*(8), 878-883.

Bakhuysen, P., Krahmer, E., & Swerts, M. (2005). Problem detection in human-machine interactions based on facial expressions of users. *Speech communication 45*(3), 343-359.

Ball, K., Berch, D. B., Helmers, K. F., Jobe, J. B., Leveck, M. D., Marsiske, M., et al. (2002). Effects of Cognitive Training Interventions With Older Adults: A Randomized Controlled Trial. *Journal- American Medical Association, 288*, 2271-2281.

Bandura, A. (1997). *Self-efficacy : the exercise of control*. New York: W.H. Freeman.

Barlow, J. H., Sturt, J., & Hearnshaw, H. (2002). Self-management interventions for people with chronic conditions in primary care: Examples from arthritis, asthma and diabetes. *Health Education Journal, 61,* 365-378.

Barnard, P. J. (1987). Cognitive resources and the learning of human-computer dialogs. In *Interfacing thought: cognitive aspects of human-computer interaction* (pp. 112-158): MIT Press.

Barrett, S. (2007). *Consumer health : a guide to intelligent decisions*. New York: McGraw-Hill Higher Education.

Bass, B. M. (1960). *Leadership, psychology, and organizational behavior*. New York: Harper.

Benyon, D., Turner, P., & Turner, S. (2005). *Designing interactive systems : people, activities, contexts, technologies*. Harlow, England; New York: Addison-Wesley.

Berg, M. H. v. d., Ronday, H. K., Peeters, A. J., Voogt-van der Harst, E. M., Munneke, M., Breedveld, F. C., et al. (2007). Engagement and satisfaction with an Internet-based physical activity intervention in patients with rheumatoid arthritis. *Rheumatology, 46*(3), 545-552.

Berg Jeths, A. v. d. (2004). *Ouderen nu en in de toekomst : gezondheid,verpleging en verzorging 2000-2020*. Houten: Bohn Stafleu Van Loghum.

Bhuyan, K. K. (2004). Health promotion through self-care and community participation: elements of a proposed programme in the developing countries. *BMC public health, 4*.

Bigelow, J. H., Cretin, S., Solomon, M., Wu, S.-Y., Cherry, J. C., Cobb, H., et al. (2000). Patient compliance with and attitudes towards Health Buddy. from http://www.rand.org/pubs/monograph_reports/MR1232/

Blaine, B., Rodman, J., & Newman, J. (2007). Weight Loss Treatment and Psychological Well-being. *Journal of Health Psychology, 12*(1), 66-82.

Blanson Henkemans, O. A., Bonacita, S., Cappiello, N., Mast, C. A. P. G. v. d., Neerincx, M. A., & Pinciroli, F. (2007). *A Hybrid Multi Agent System Architecture for Distributed Supervision of Chronic Patients in the eHealth Setting.* Paper presented at the Euromedia 2007, Delft, the Netherlands.

Blanson Henkemans, O. A., Boog, P. J. M. v. d., Lindenberg, J., Mast, C. A. P. G. v. d., Neerincx, M. A., & Zwetsloot-Schonk, J. H. M. (Submitted). An Online Lifestyle Diary with a Persuasive Computer Assistant Providing Feedback on Self-Management. *Special Issue Technology & Health Care "Smart environments: technology to support healthcare"*.

Blanson Henkemans, O. A., Caine, K. E., Rogers, W. A., Fisk, A. D., Neerincx, M. A., & Ruyter, B. d. (2007). *Medical Monitoring for Independent Living: User-Centered Smart Home Technologies for Older Adults.* Paper presented at the Med-e-Tel 2007, Luxemburg, Luxemburg.

Blanson Henkemans, O. A., Mast, C. A. P. G. v. d., Lindenberg, J., Neerincx, M. A., & Zwetsloot-Schonk, J. H. M. (2008). *Incremental and Medically Ethical Design of Usable eHealth Support for Disease Self-Regulation*. Paper presented at the Building Comfortable and Liveable Environments for All.

Blanson Henkemans, O. A., Neerincx, M. A., Lindenberg, J., & Mast, C. A. P. G. v. d. (2006). *SuperAssist: A User-Assistant Collaborative Environment* *for the supervision of medical instrument use at home.* Paper presented at the Pervasive Health Conference and Workshops 2006, Innsbruck.

Blanson Henkemans, O. A., Neerincx, M. A., Lindenberg, J., & Mast, C. A. P. G. v. d. (2006). *SuperAssist: supervision of patient self-care and medical adherence.* Paper presented at the 16th Triennial Congress of the the International Ergonomics Association, Maastricht, the Netherlands.

Blanson Henkemans, O. A., Rogers, W. A., Fisk, A. D., Neerincx, M. A., Lindenberg, J., & Mast, C. A. P. G. v. d. (2008). Usability of an Adaptive Computer Assistant that Improves Self-care and Health Literacy of Older Adults. *Methods of information in medicine. Methodik der Information in der Medizin., 47*(1), 82.

Blanson Henkemans, O. A., Sawirjo, V. M., Mast, C. A. P. G. v. d., Neerincx, M. A., & Lindenberg, J. (2008). *A computer assistant for remote collaborative troubleshooting of domestic medical instruments*. Paper presented at the Second International Conference on Pervasive Computing Technologies for Healthcare.

Bodenheimer, T., & Grumbach, K. (2003). Innovations In Primary Care - Electronic Technology: A Spark to Revitalize Primary Care? *JAMA : the journal of the American Medical Association., 290*(2), 259.

Bojic, M., Blanson Henkemans, O. A., Neerincx, M. A., Mast, C. A. P. G. v. d., & Lindenberg, J. (2009). *Effects of Multimodal Feedback on the Usability of Mobile Diet Diary for Older Adults.* Paper presented at the HCI International 2009, San Diego, CA, USA.

Breemen, A., Yan, X., & Meerbeek, B. (2005). iCat: an animated user-interface robot with personality. *AAMAS'05*, 143-144.

Brooks, G. A., Butte, N. F., Rand, W. M., Flatt, J. P., & Caballero, B. (2004). Chronicle of the Institute of Medicine physical activity recommendation: how a physical activity recommendation came to be among dietary recommendations. *American Journal Of Clinical Nutrition, 79*, 921S-930S.

Campbell, R. J., & Nolfi, D. A. (2005). Teaching elderly adults to use the Internet to access health care information: before-after study. *Journal of medical Internet research, 7*(2), e19.

Card, S. K., Moran, T. P., & Newell, A. (1983). *The psychology of human-*

computer interaction. Hillsdale, N.J.: L. Erlbaum Associates.

Carroll, J. B. (1993). *Human cognitive abilities : a survey of factor-analytic studies*. Cambridge; New York: Cambridge University Press.

Carver, C. S., & Scheier, M. F. (2002). Control Processes and Self-Organization as Complementary Principles Underlying Behavior. *Personality and Social Psychology Review, 6*(4), 304-315.

Cash, T. F., Morrow, J. A., Hrabosky, J. I., & Perry, A. A. (2004). How Has Body Image Changed? A Cross-Sectional Investigation of College Women and Men from 1983 to 2001. *Journal of Consulting and Clinical Psychology, 72*(6), 1081-1089.

Christensen, A. J., & Smith, T. W. (1995). Personality and Patient Adherence: Correlates of the Five-Factor Model in Renal Dialysis. *Journal of behavioral medicine., 18*(3), 305.

Cooney, J. (2001). *Development and Application of Condition Based Maintenance and Management in Food Manufacturing.* Unpublished PhD Thesis, National University of Ireland, Cork. Ireland.

Coyle, C., Doherty, G., Matthews, M., & Sharry, J. (2007). Computer in talk-based mental health interventions. *Interacting with computers., 19*, 545-562.

Czaja, S. J., Charness, N., Fisk, A. D., Hertzog, C., Nair, S. N., Rogers, W. A., et al. (2006). Factors Predicting the Use of Technology: Findings From the Center for Research and Education on Aging and Technology Enhancement (CREATE). *Psychology and aging., 21*(2), 333-352.

Dix, A. J., Finlay, J. E., Abowd, G. D., & Beale, R. (1998). *Human-Computer Interaction. Second Edition*: Prentice Hall, ESM Marketing-Computer Science, 1 Lake Street, Upper Saddle River, NJ 07458.

Dourish, P. (2006). *Re-space-ing place: "place" and "space" ten years on*. Paper presented at the Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work.

Dulmen, S. v., Sluijs, E., van Dijk, L., de Ridder, D., Heerdink, R., & Bensing, J. (2007). Patient adherence to medical treatment: a review of reviews. *BMC health services research, 7*(55), 1-13.

Dumay, A. C. (2007). Innovating eHealth in the Netherlands. *Studies in health technology and informatics, 127*, 157-165.

Eckel, C. C., & Grossman, P. J. (1998). Are Women Less Selfish Than Men?: Evidence From Dictator Experiments. *The Economic Journal, 108*(448), 726-735.

Emery, V. K., Edwards, P., J., Jacko, J., A., Moloney, K., P., Barnard, L., Kongnakorn, T., et al. (2002). Toward achieving universal usability for older adults through multimodal feedback. *SIGCAPH Comput. Phys. Handicap.*(73-74), 46-53.

Endsley, M. R., & Kiris, E. O. (1995). The Out-of-the-Loop Performance Problem and Level of Control in Automation. *Human factors : the journal of the Human Factors Society., 37*(2), 381.

Eng, T. R. (2001). *The eHealth landscape : a terrain map of emerging information and communication technologies in health and heath care*. Princeton, NJ: Robert Wood Johnson Foundation.

Etzwiler, D. D., Rukeyser, J., Steinbock, C., Agins, B. D., & Bodenheimer, T. (2003). Self-management of Chronic Disease. *Journal- American Medical Association, 289*, 1508-1509.

European Food Safety Authority (EFSA). (2006). *Development of Food-Based Dietary Guidelines.* Paper presented at the Summary Report EFSA Scientific Colloquium Parma, Italy.

Eysenbach, G. (2001). What is e-health? *Journal of medical Internet research, 3*(2).

Fischer, G. (2001). User Modeling in Human-Computer Interaction. *User Modeling and User-Adapted Interaction, 11*(1/2), 65-86.

Fisk, A. D., Rogers, W. A., Charness, N., Czaja, S. J., & Sharit, J. (2004). *Designing for Older Adults: Principles and Creative Human Facotrs Appraoches* (1 ed.). Boca Raton, FL: CRC Press.

Fogg, B. J. (2003). *Persuasive technology : using computers to change what we think and do*. Amsterdam; Boston: Morgan Kaufmann Publishers.

Gaillard, A. W. K. (2003). Fatigue Assessment and Performance Protection. NATO *Science Series Sub Series I Life and Behavioural Sciences, 355*, 24-35.

Garrett, J. J. (2003). *The elements of user experience : user-centered design for the web*. New York, NY; Indianapolis, Ind.: American Institute of Graphic Arts ; New Riders.

Gitlin, L. N., & Burgh, D. (1995). Issuing Assistive Devices to Older Patients in Rehabilitation: An Exploratory Study. *American Journal of Occupational Therapy, 49*(10), 994.

Gloyd, D. M. (2003). *Positive user experience and medical adherence*. Paper presented at the Proceedings of the 2003 international conference on Designing pleasurable products and interfaces.

Go, K., & Carroll, J. M. (2004). The blind men and the elephant: Views of scenario-based system design. *Interactions -New York-, 11*(6), 44-54.

Golin, C. E., DiMatteo, M. R., Leake, B., Duan, N., & Gelberg, L. (2001). A diabetes-specific measure of patient desire to participate in medical decision making. *The Diabetes educator, 27*(6), 875-886.

Gollwitzer, P. M., & Oettingen, G. (2008). The question-behavior effect from an action control perspective. *Journal of Consumer Psychology, 18*(2), 107-110.

Graziola, I., Rocchi, C., Goren-Bar, D., Pianesi, F., Stock, O., & Zancanaro, M. (2005). Delegation Based Multimedia Mobile Guide. *Lecture notes in computer science.*(3814), 328-331.

Grill, T., Khalil Ibrahim, I., & Kotsis, G. (2005). *Agent interaction in ambient intelligent environments.* Paper presented at the 13th DPS workshop, Okinawa - Japan.

Grootjen, M., Neerincx, M. A., & Veltman, J. A. (2006). Cognitive task load in a naval ship control centre: from identification to prediction. *Ergonomics, 49*(12-13), 12-13.

Grundy, J., & Hosking, J. (2002). Developing adaptable user interfaces for component-based systems. *Interacting with computers., 14*(3), 175-194.

Haan, G., Blanson Henkemans, O. A., & Ahluwalia, A. (2005). *Personal assistants for healthcare treatment at home*. Paper presented at the Proceedings of the 2005 annual conference on European association of cognitive ergonomics.

Hart, S. G., & Stavenland, L. E. (1988). Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Human Mental Workload* (pp. 139-183): Elsevier.

Haynes, R. B., Yao, X., Degani, A., Kripalani, S., Garg, A., & McDonald, H. P. (2005). Interventions to enhance medication adherence. *Cochrane database of systematic reviews (Online)*(4).

Higgins, J. P. T., & Green, S. (2008). *Cochrane Handbook for Systematic Reviews of Interventions* Retrieved February 2008, from http://www.cochrane-handbook.org

Hindus, D. (1999). The Importance of Homes in Technology Research. *Lecture notes in computer science.*(1670), 199.

Hoc, J.-M., Cacciabue, P. C., Hollnagel, E., & Norton, M. J. (1996). Expertise and Technology, Cognition and Human-Computer Cooperation. *Journal of the American Society for Information Science., 47*(9), 722.

Hollnagel, E. (2003). *Handbook of cognitive task design*. Mahwah, N.J.: Lawrence Erlbaum Publishers.

Hollnagel, E., & Woods, D. D. (2005). *Joint cognitive systems : foundations of cognitive systems engineering*. Boca Raton, FL: Taylor & Francis.

Houweling, S. T., KLeefstra, N., Verhoeven, S., Ballegooie, E. v., & Bilo, H. J. G. (2004). *Protocollaire Diabeteszorg, Mogelijkheden voor Taakdelegatie (Formal Diabetes Care, Possibilites for Task Delegation)* (2 ed.). Zwolle: Isala Series.

Ishizuka, M., & Prendinger, H. (2004). *Life-like characters : tools, affective functions and applications*. Berlin [u.a.]: Springer.

Jacko, J., Emery, V. K., Edwards, P., Ashok, M., Barnard, L., Kongnakorn, T., et al. (2004). The effects of multimodal feedback on older adults' task performance given varying levels of computer experience. *Behaviour & Information Technology, 23*(4), 247-264.

Jacobson, I., Christersson, M., Johnsson, P., & Overgaard, G. (1992). *Object Oriented Software Engineering: A Use Case Driven Approach*. Reading, MA: Addison-Wesley.

Jeurissen, E., & Spanje, M. v. (2001). *Rondom dik : zin en onzin over zwaarlijvigheid*. Amsterdam: Ambo.

Johnson, S. D., Ferej, A. K., Flesher, J. W., Jehng, J.-C. J., & National Center for Research in Vocational, E. (1996). *Enhancing electrical troubleshooting skills in a computer-coached practice environment*. Berkeley, Ca.: National Center for Research in Vocational Education.

Jonassen, D. H., Howland, J., Moore, J., & Marra, R. M. (2003). *Learning to solve problems with technology : a constructivist perspective*. Upper Saddle River, N.J.: Merrill.

Kahai, S. S., Sosik, J. J., & Avolio, B. J. (2004). Effects of Participative and Directive Leadership in Electronic Groups. *Group & Organization Management, 29*(1), 67-105.

Kane, S. K., Wobbrock, J. O., & Smith, I. E. (2008). *Getting Off the Treadmill: Evaluating Walking User Interfaces for Mobile Devices in Public Spaces.* Paper presented at the 10th International Conference on Human-Computer Interaction with Mobile Devices and Services, Amsterdam, teh Netherlands.

Kaplan, B., & Litewka, S. (2008). Ethical Challenges of Telemedicine and Telehealth. *Cambridge Quarterly of Healthcare Ethics, 17*, 401-416

Kaplan, R. M., Atkins, C. J., & Reinsch, S. (1984). Specific efficacy expectations mediate exercise compliance in patients with COPD. *Health psychology : official journal of the Division of Health Psychology, American Psychological Association, 3*(3), 223-242.

Karter, A. J., Ackerson, L. M., Darbinian, J. A., D'Agostino, R. B., Jr., Ferrara, A., Liu, J., et al. (2001). Self-monitoring of blood glucose levels and glycemic control: the Northern California Kaiser Permanente Diabetes registry. *The American journal of medicine, 111*(1), 1-9.

Kelley, J. F., & Thomas, J. W. (1983). *Validating an empirical methodology for writing user-friendly natural language computer applications*. Yorktown Heights, N.Y.: IBM Thomas J. Watson Research Center.

Kemper, H. C. G. (2004). How Important is Daily Physical Activity to Public Health? Data Analyses from the Amsterdam Growth and Health Longitudinal Study. *European Journal of Public Health, 14*(Supplement), 10.

Kennedy, A., Rogers, A., & Bower, P. (2007). Support for self care for patients with chronic disease. *British Medical Journal* (7627), 968-970.

Kidd, C. D., Orr, R., Abowd, G. D., & Atkeson, C. G. (1999). The Aware Home: A Living Laboratory for Ubiquitous Computing Research. *Lecture notes in computer science* (1670), 191.

Kim, E. B., & Schniederjans, M. J. (2004). The Role of Personality in Web-based Distance Education Courses. *Communications- ACM, 47*, 95-98.

Kirwan, B., & Ainsworth, L. K. (1992). *A Guide to task analysis*. London; Washington, DC: Taylor & Francis.

Kjeldskov, J., & Stage, J. (2004). New techniques for usability evaluation of mobile systems. *International journal of human-computer studies., 60*(5), 599.

Kneckt, M. (2000). *Psychological features characterizing oral health behavior, diabetes self-care and health status among IDDM patients.* Oulun yliopisto, Oulu.

Krahmer, E., Ruttkay, Z., Swerts, M., & Wesselink, W. (2002). *Pitch, Eyebrows and the Perception of Focus.* Paper presented at the Speech Prosody 2002, Aix-en-Provence, France.

Krahmer, E., Swerts, M., Theune, M., & Weegels, M. (2002). The dual of denial: Two uses of disconfirmations in dialogue and their prosodic correlates. *Speech communication., 36*(1), 133.

Kreijl, C. F. v., & Knaap, A. G. A. C. (2004). *Ons eten gemeten : gezonde voeding en veilig voedsel in Nederland*. Bilthoven; Houten: RIVM ; Bohn Stafleu Van Loghum.

Krogt, R. v. d., Bos, A., & Witteveen, C. (2002). Replanning in a Resource-Based Framework. *Lecture notes in computer science.*(2322), 148-158.

Kuijten, L.L.P.J.M. (2006) Patient's Emotional Expressiveness Towards a Human or Digital Assistant. Master's Thesis – Cognitive Psychology, University Maastricht.

Kushniruk, A. W., & Borycki, E. (2008). *Human, social, and organizational aspects of health information systems*. Hershey: Medical Information Science Reference.

Landers, R. N., & Lounsbury, J. W. (2006). An investigation of Big Five and narrow personality traits in relation to Internet usage. *Computers In Human Behavior, 22*(2), 283-293.

Larizza, C., Bellazzi, R., Stefanelli, M., Ferrari, P., De Cata, P., Gazzaruso, C., et al. (2006). The M2DM Project - The Experience of Two Italian Clinical Sites with Clinical Evaluation of a Multi-access Service for the Management of Diabetes Mellitus Patients. *Methods of Information in Medicine, 45*(1), 79-84.

Leventhal, E. A., Hansell, S., Diefenbach, M., Leventhal, H., & Glass, D. C. (1996). Negative Affect and Self-Report of Physical Symptoms: Two Longitudinal Studies of Older Adults. *Health Psychology, 15*(3), 193-199.

Leventhal, H., Halm, E., Horowitz, C., Leventhal, E., & Ozakinci, G. (2004). Living with chronic illness: A contextualized, self-regulation approach. In S. Sutton, A. Baum & M. Johnston (Eds.), *The Sage Handbook of Health Psychology.* . London: Sage.

Leventhal, H., & Mora, P. A. (2005). Is there a Science of the Processes Underlying Health and Illness Behaviors? A Comment on Maes and Karoly. *Applied Psychology: an International Review, 54*(2), 255-266.

Leventhal, H., Weinman, J., Leventhal, E. A., & Phillips, L. A. (2008). Health Psychology: The Search for Pathways Between Behavior and Health. *Annual Review of Psychology, 59*, 477-506.

Lindenberg, J., Nagata, S. F., & Neerincx, M. A. (2003). *Personal Assistant for onLine Services: Addressing Human Factors, Human Centered Computing.* Paper presented at the Human Computer Interaction International Conference 2003, Crete, Greece.

Lindenberg, J., Pasman, W., Kranenborg, K., Stegeman, J., & Neerincx, M. (2007). Improving service matching and selection in ubiquitous computing environments: a user study. *Personal and Ubiquitous Computing, 11*(1), 59-68.

Lippa, K. D., Klein, H. A., & Shalin, V. L. (2008). Everyday Expertise: Cognitive Demands in Diabetes Self-Management. *Human Factors -New York Then Santa Monica-, 50*(1), 112-120.

Looije, R., Cnossen, F., & Neerincx, M. A. (2006). *Incorporating guidelines for health assistance into a socially intelligent robot.* Paper presented at the Proceedings of 15th IEEE Ro-Man, University of Hertfordshire, Hatfield, UK.

Looije, R., Neerincx, M. A., & Cnossen, F. (2009). Persuasive robotic assistant for health self-management of older adults: Design and evaluation of social behaviors. Submitted to *Special issue on Human-computer interaction for medicine and health care (HCI4MED) International Journal of Human-Computer Studies (IJHCS).*

Lorig, K. R. & Holman, H. (2003). Self-management education: history, definition, outcomes, and mechanisms. *Annals of behavioral medicine : a publication of the Society of Behavioral Medicine, 26,* 1-7.

Lorig, K., & Fries, J. F. (2006). *The arthritis helpbook : a tested self-management* *program for coping with arthritis and fibromyalgia*. Cambridge, Mass.; London: Da Capo Lifelong; Perseus Running, distributor.

Lustria, M. L. A., Cortese, J., Noar, S. M., & Glueckauf, R. L. (2008). Computer-tailored health interventions delivered over the web: Review and analysis of key components *Patient Education and Counseling*.

MacIntyre, B., Mynatt, E. D., Voida, S., Hansen, K. M., Tullio, J., & Corso, G. M. (2001). *Support for multitasking and background awareness using interactive peripheral displays*. Paper presented at the Proceedings of the 14th annual ACM symposium on User interface software and technology.

Maes, P. (1995). Intelligent Software. *Scientific American., 273*(3), 84.

Maes, S., & Karoly, P. (2005). Self-Regulation Assessment and Intervention in Physical Health and Illness: A Review. *Applied Psychology, 54*(2), 267-299.

Maguire, M. (2001). Methods to support human-centred design. *International Journal of Human Computer Studies, 55*, 587-634.

Mayhorn, C. B., Rogers, W. A., & Fisk, A. D. (2004). Designing technology based on cognitive aging principles. In D. C. Burdick & S. Kwon (Eds.), *Gerotechnology: Research and practice in technology and aging – A textbook and reference for multiple disciplines* (pp. 42-53). New York, NY: Springer.

McLaughlin, A. C., Rogers, W., & Fisk, A. (2004). Age-Related Glucometer Design and Selection: Tools and Principles for Optimal Solutions. *Diabetes Technology and Therapeutics, 6*(3), 319-325.

McLaughlin, A. C., Rogers, W. A., Fisk, A. D., & Essa, I. A. (2005). *Designing a Technology Coach for Older Adults.* Paper presented at the HCI International 2005, Las Vegas, NV, United States of America.

Miller, W. R., & Rollnick, S. (1991). *Motivational interviewing : preparing people to change addictive behavior*. New York [u.a.: Guilford Press.

Morrow, D., Clark, D., Tu, W., Wu, J., Weiner, M., Steinley, D., et al. (2006). Correlates of Health Literacy in Patients with Chronic Heart Failure. *Gerontologist, 46*(5), 669-676.

Muehrer, R. J., & Becker, B. N. (2005). Psychosocial Factors in Patients With Chronic Kidney Disease: Life After Transplantation: New Transitions in Quality of Life and Psychological Distress. *Seminars in Dialysis, 18*(2), 124-131.

Murray, M. D., Wu, J., Tu, W., Clark, D. O., Weiner, M., Morrow, D. G., et al. (2004). Health literacy predicts medication adherence. *Clinical Pharmacology and Therapeutics -St Louis-, 75*(2), P76.

Murray, S. A., Gage, D. W., Bott, J. P., Murphy, D. W., Bryan, W. D., Space, et al. (1998). Advanced User Interface Design and Advanced Internetting for Tactical Security Systems. from http://handle.dtic.mil/100.2/ADA422503

Mykityshyn, A. L., Fisk, A. D., & Rogers, W. A. (2002). Learning to Use a Home Medical Device: Mediating Age-Related Differences with Training. *Human Factors -New York Then Santa Monica-, 44*, 354-364.

Mynatt, E. D., & Rogers, W. A. (2002). Developing Technology to Support the Functional Independence of Older Adults. *Ageing International, 27*, 24-41.

Nagata, S. F., Oostendorp, H. v., & Neerincx, M. A. (2004). *Interaction design concepts for a mobile personal assistant*. Paper presented at the Proceedings of the conference on Dutch directions in HCI.

Nardi, B. A. (1996). *Context and consciousness : activity theory and human-computer interaction*. Cambridge, Mass.: MIT Press.

Neerincx, M. A., & Lindenberg, J. (2008). Situated cognitive engineering for complex task environments. In J. M. C. Schraagen, L. Militello, T. Ormerod & R. Lipshitz (Eds.), *Natural Decision Making & Macrocognition*. Aldershot, UK: Ashgate Publishing Limited.

Neerincx, M. A., Lindenberg, J., & Grootjen, M. (2005). Accessibility on the Job: Cognitive Capacity Driven Personalization. *HCII 2005, 7*(Universal Access in HCI: Exploring New Interaction Environments), 10.

Neerincx, M. A., Lindenberg, J., Smets, N., Grant, T., Bos, A., Olmedo-Soler, A., et al. (2006). *Cognitive engineering for long duration missions: human-machine collaboration on the Moon and Mars*. Paper presented at the Second IEEE International Conference on Space Mission Challenges for Information Technology.

Nichols, T. A., Rogers, W. A., & Fisk, A. D. (2003). Do You Know How Old Your Participants Are? *Ergonomics in Design, 11,* 22-26.

Nielsen, J. (1993). *Usability engineering*. Boston: Academic Press.
Nijland, N., van Gemert-Pijnen, J., Boer, H., Steehouder, M. F., & Seydel, E. R. (2008). Evaluation of internet-based technology for supporting self-care: problems encountered by patients and caregivers when using self-care applications. *Journal of medical Internet research, 10*(2), e13.
Nooijer, J. d., Oenema, A., Kloek, G., Brug, H., Vries, H. d., & Vries, N. d. (2005). *Bevordering van gezond gedrag via internet: nu en in de toekomst*. Maastricht: Universiteit Maastricht.
Norman, D. A. (1988). *The psychology of everyday things*. New York: Basic Books.
Norman, G. J., Zabinski, M. F., Adams, M. A., Rosenberg, D. E., Yaroch, A. L., & Atienza, A. A. (2007). A review of eHealth interventions for physical activity and dietary behavior change. *American journal of preventive medicine, 33*(4), 336-345.
O'Hea, E. L., Grothe, K. B., Bodenlos, J. S., Boudreaux, E. D., White, M. A., & Brantley, P. J. (2005). Predicting Medical Regimen Adherence: The Interactions of Health Locus of Control Beliefs. *Journal of Health Psychology, 10*(5), 705-717.
Osmani, V., Balasubramaniam, S., & Botvich, D. (2008). Human activity recognition in pervasive health-care: Supporting efficient remote collaboration. *Journal of Network and Computer Applications, 31*(4), 628-655.
Pagliari, C. (2007). Design and evaluation in eHealth: challenges and implications for an interdisciplinary field. *Journal of medical Internet research, 9*(2).
Payne, T., Sycara, K., Lewis, M., Lenox, T. L., & Hahn, S. K. (2000). *Varying the User Interaction within Multi-Agent Systems.* Paper presented at the Fourth International Conference on Autonomous Agents.
Perez, R. (1991). A view form troubleshooting. In M. Smith (Ed.), *Toward a Unified Theory of Problem Solving*. Hillsdale, NJ: Erlbaum.
Picard, R. W., Vyzas, E., & Healey, J. (2001). Toward Machine Emotional Intelligence: Analysis of Affective Physiological State. *IEEE Transactions on Pattern Analysis and Machine Intelligence Pami, 23*, 1175-1191.
Post, W. M., Cremers, A. H. M., & Blanson Henkemans, O. A. (2004).

A Research Environment for Meeting Behavior. Paper presented at the 3rd Workshop on Social Intelligence Design.

Preece, J. (1994). *Human-computer interaction*. Wokingham, England; Reading, Mass.: Addison-Wesley Pub. Co.

Preece, J., Abras, C., & Maloney-Krichmar, D. (2004). Designing and evaluating online communities: research speaks to emerging practice. *International Journal of Web Based Communities, 1*(1), 2-18.

Pynadath, D. V., & Tambe, M. (2003). An Automated Teamwork Infrastructure for Heterogeneous Software Agents and Humans. *Autonomous Agents and Multi-Agent Systems, 7*(1-2), 1-2.

Ramaekers, J. E. F. D. (2005). Telebegeleiding van chronische patiënten. *ZM,* 14-17.

Rasmussen, J. (1986). *Information processing and human-machine interaction : an approach to cognitive engineering*. New York: North-Holland.

Rasmussen, J. (Ed.). (1984). Strategies for state identification and diagnosis in supervisory control tasks, and design of computer-based support systems. In W. B. Rouse (Ed.), *Advances in man–machine systems research*, Vol. 1 (pp. 139–193). Greenwich: JAI Press.

Righi, C., & James, J. (2007). *User-centered design stories : real-world UCD case files*. Amsterdam; Boston: Elsevier/Morgan Kaufman.

Rogers, W. A., Essa, I. A., & Fisk, A. D. (2007). Designing a Technology Coach - A multidisciplinary team models a system that can alert users of a complex medical device when they make an error. *Ergonomics in design : the magazine of human factors applications., 15*(3), 17.

Rogers, W. A., Mykityshyn, A. L., Campbell, R. H., & Fisk, A. D. (2001). Only 3 easy steps? User-centered analysis of a "simple" medical device. *Ergonomics in Design, 9*, 6-14.

Rosson, M. B., & Carroll, J. M. (2002). *Usability engineering : scenario-based development of human-computer interaction*. San Fancisco: Academic Press.

Rotter, J. B. (1954). *Social learning and clinical psychology*. New York: Prentice-Hall.

Russell, S. J., & Norvig, P. (2003). *Artificial intelligence : a modern approach*. Upper Saddle River, NJ [u.a.]: Prentice Hall.

Sackett, D. L., & Snow, J. C. (1979). The magnitude of compliance and non-compliance. In R. B. Haynes, W. D. Taylor & D. L. Sackett (Eds.), *Compliance in health care* (pp. 11–22.). Baltimore, London: The John Hopkins University Press.

Santa Ana, E. J., Martino, S., Ball, S. A., Nich, C., Frankforter, T. L., & Carroll, K. M. (2008). What is usual about "treatment-as-usual"? Data from two multisite effectiveness trials. *Journal of substance abuse treatment, 35*(4), 369-379.

Schaafstal, A., Schraagen, J. M., & van Berlo, M. (2000). Cognitive Task Analysis and Innovation of Training: The Case of Structured Troubleshooting. *Human Factors -New York Then Santa Monica-, 42*, 75-86.

Schouten, J. A. M. (2004). *Anamnese en advies : richtlijnen voor de informatie-uitwisseling tussen arts en patient*. Houten: Bohn Stafleu Van Loghum.

Shipley, W. C. (1986). *Shipley institute of living scale : revised manual*. Los Angeles, Calif.: WPS, Western Psychological Services.

Shneiderman, B. (1987). *Designing the user interface : strategies for effective human-computer interaction*. Reading, Mass.: Addison-Wesley.

Slegers, K. (2006). *Succesful cognitive aging : the use of computers and the internet to support autonomy in later life.* Neuropsych Publishers, Maastricht.

Smets, N., J. J. M., Brake, G., M. te, Neerincx, M., A., & Lindenberg, J. (2008). *Effects of mobile map orientation and tactile feedback on navigation speed and situation awareness*. Paper presented at the Proceedings of the 10th international conference on Human computer interaction with mobile devices and services.

Somech, A. (2005). Directive Versus Participative Leadership: Two Complementary Approaches to Managing School Effectiveness. *Educational Administration Quarterly, 41*(5), 777-800.

Statistics Netherlands (CBS). (2007a). *Age and Overweight Prime Risk Factors for Diabetes*. Retrieved. from http://www.cbs.nl/en-GB/menu/themas/gezondheid-welzijn/publicaties/artikelen/archief/2007/2007-2232-wm.htm.

Statistics Netherlands (CBS). (2007b). *Leefstijl Nederlander Niet Verbeterd*

(Lifestyle Dutch Not Improved). Retrieved. from http://www.cbs.nl/NR/rdonlyres/EFCD6D79-C4A4-42C4-BCA9-D8EDFE67039E/0/pb07n021.pdf.

Streefkerk, J. W., Esch-Bussemakers, M. v., & Neerincx, M. (2007). Context-Aware Notification for Mobile Police Officers In D. Harris (Ed.), *Engineering Psychology and Cognitive Ergonomics* (Vol. 4562, pp. 436-445). Berlin / Heidelberg: Springer.

Stroetmann, K. A., Jones, T., Dobrev, A., & Stroetmann, V. N. (2006). *eHealth is Worth it: The economic benefits of implemented eHealth solutions at ten European sites*. Retrieved. from http://ec.europa.eu/information_society/activities/health/docs/publications/ehealthimpactsept2006.pdf.

Suchman, A. L., Botelho, R. J., & Walker, P. H. (1998). *Partnerships in healthcare : transforming relational process*. Rochester, N.Y.: University of Rochester Press.

Thompson, M. M., Naccarato, M. E., Parker, K. C. H., & Moskowitz, G. B. (2001). The Personal Need for Structure and Personal Fear of Invalidity Measures: historical perspectives, current application and future directions. In G. B. Moskowitz (Ed.), *Cognitive Social Psychology: On the Tenure and Future of Social Cognition* (pp. 19-39). Hilsdale, N.J.: Erbaum.

Thurstone, L. L. (1934). *Tests used in a study of mental abilities*. Chicago, Ill.: The University of Chicago.

Torkzadeh, G., Chang, J. C., & Demirhan, D. (2006). A contingency model of computer and Internet self-efficacy. *Information and Management, 43*(4), 541-550.

Tsiknakis, M., & Kouroubalia, A. (2008). Organizational factors affecting successful adoption of innovative eHealth services: A case study employing the FITT framework *International Journal of Medical Informatics, 78*(1), 39-52.

Tufano, J. T., & Karras, B. T. (2005). Mobile eHealth interventions for obesity: a timely opportunity to leverage convergence trends. *Journal of medical Internet research, 7*(5), e58.

United States Department of Health and Human Services. (2000). *Healthy* *people 2010*. Washington, DC: U.S. Dept. of Health and Human Services.

Vermeulen, I., Bohte, S., Somefun, K., & Poutré, H. (2007). Multi-agent Pareto appointment exchanging in hospital patient scheduling. *Service Oriented Computing and Applications, 1*(3), 185-196.

Vredenburg, K., Isensee, S., & Righi, C. (2002). *User-centered design : an integrated approach*. Upper Saddle River, NJ: Prentice Hall PTR.

Vrijhoef, H. J. M., Janssen-Boyne, J., Engering, G., Kragten, J. A., De Weerd, G. J., Frederix, M., et al. (2008). The health buddy: next term telemonitoring system for patients with heart failure. *European Journal of Heart Failure Supplements, 5*(1), 174.

Wahl, C., Gregoire, J. P., Teo, K., Beaulieu, M., Labelle, S., Leduc, B., et al. (2005). Concordance, compliance and adherence in healthcare: closing gaps and improving outcomes. *Healthcare quarterly (Toronto, Ont.), 8*(1), 65-70.

Webster, D. M., & Kruglanski, A. W. (1998). Cognitive and Social Consequences of the Need for Cognitive Closure. *European Review of Social Psychology, 8*, 133-174.

Wechsler, D. (1981). *Manual for Wechsler Memory Scaled—Revised*. New York, NY: The Psychological Corporation.

Weiser, M. (1991). *The computer for the 21st century*. From http://www.ubiq.com/hypertext/weiser/SciAmDraft3.html

Welschen, L. (2008). *Disease Management for Patients with Type 2 Diabetes: Towards Patient Empowerment*. Enschede: Gildeprint Drukkerrijen BV.

Werther, B., & Schnieder, E. (2005). *Formal Cognitive Resource Model: Modeling of human behavior in complex work environments.* Paper presented at the International Conference on Intelligent Computational Intelligence for Modelling, Control and Automation 2005.

Wijler, D., Urowitz, S., Apatu, E., DeLenardo, C., Eysenbach, G., Harth, T., et al. (2008). Patient Accessible Electronic Health Records: Exploring Recommendations for Successful Implementation Strategies. *Journal of Medical Internet Research, 10*(4), e34.

Williams, G. C., Deci, E. L., & Ryan, R. M. (1998). Building Health-Care Partnerships by Supporting Autonomy: Promoting Maintained

Behavior Change and Positive Health Outcomes. *Partnerships in healthcare: Transforming relational process*, 67-87.

Wise, M., Han, J. Y., Shaw, B., McTavish, F., & Gustafson, D. H. (2008). Effects of using online narrative and didactic information on healthcare participation for breast cancer patients. *Patient Education and Counseling, 70*(3), 348-356.

Wooldridge, M. J. (2004). *An introduction to multiagent systems*. Chichester [u.a.]: Wiley.

World Health Organization (2003a). *Adherence to long-term therapies: evidence for action*. Retrieved. from http://www.who.int/chp/knowledge/publications/adherence_full_report.pdf.

World Health Organization (2003b). *Obesity and Overweight*. Retrieved. from http://www.who.int/hpr/NPH/docs/gs_obesity.pdf.

World Medical Association (2004). World Medical Association declaration of Helsinki ethical principles for medical research involving human subjects. from http://www.wma.net/e/policy/b3.htm

Xiao, Y., Shen, X., Sun, B., & Cai, L. (2006). Security and Privacy in RFID and Applications in Telemedicine. *IEEE Communications Magazine, 44*(4), 64-72.

Zhang, Z., & Zhang, C. (2007). Building agent-based hybrid intelligent systems: A case study. *Web Intelligence and Agent Systems: An international journal, 5*(3), 255-271.

Zijlstra, F. R. H. (1993). *Efficiency in work behaviour : a design approach for modern tools*. Delft: Delft University Press.

SUMMARY

There is a shift from the individual patient receiving one-sidedly treatment from the health care system towards a more independent, self-determining and active position wherein the emphasis lies on achieving self-care objectives. This is especially of importance for the growing group of people with chronic and lifestyle related diseases, such as diabetes type II and overweight. By deploying Information and Communication Technology (ICT) in the medical domain, eHealth services can stimulate self-care. Moreover, in accordance with the SuperAssist model, in which ePartners, offer personalized support, Personal Computer Assistants can enhance eHealth services. However, there is little empirical research on how eHealth services with Personal Computer Assistants can support self-care and on what their effects are. Consequently, we studied which Assistant features can enhance eHealth services and support self-care, in relation to troubleshooting of domestic medical instruments and adherence to self-care objectives. Our focus lies on the influence of Human-Computer Assistant interaction, covering feedback style and appearances on the self-care process and outcome measures. Specifically, we looked at two feedback styles, i.e., cooperative, which is coaching, educating and aims at high participation of the user to develop long-term ability, and directive, which is instructing, reporting and aims at compliance of the user to achieve quick problem solving. Also, we looked at different assistant appearances, i.e., text and images and animated avatar. Finally, we studied how user characteristics, i.e., user, context and tools, and Human Factors, i.e., demographics, cognitive abilities and personality traits explain variance in the performance of self-care activities.

Chapter 2 discusses the use of the Cognitive Engineering (CE) approach for the development of eHealth services with Personal Computer Assistants. This

approach has proven successful in other domains that, similarly to the health care service, deal with complex situations, are prone to errors, and require high level attention from different actors, with different needs. The approach starts with the analysis of the medical work domain and technical support. This covers self-care, Human Factors and envisioned technology. Subsequently, the analysis outcomes are used to set up design specifications, including functions, claims and scenarios. These specifications are used to iteratively conduct experiments in Smart Home Lab and field setting on the effect of Personal Computer Assistants with different feedback styles and appearance in self-care.

For the proposed Personal Computer Assistants to work on a large scale, it is a prerequisite that integrating them in large-scale eHealth services is technically feasible. Chapter 3 addresses this issue and discusses the design and qualitative evaluation of an eHealth framework with Personal Computer Assistants. With the use of SuperAssist project's core functions and scenarios, we designed a Digital Diabetes Diary with Personal Computer Assistants, based on a Multi Agent System (MAS). Subsequently, we evaluated whether the framework facilitates multiple distributed agents acting as independent intelligent actors and as Personal Computer Assistants for easy medical data and information management. Results of our study showed that it is technically feasible to develop an eHealth framework with Personal Computer Assistants. Moreover, the Digital Diary with Computer Assistant fulfilled our design specifications in relation to personalized support of data management by involved users and agents. The evaluated framework was used in the following studies.

As medical instruments are increasingly used to support self-monitoring, patient's maintenance and troubleshooting of such instruments is becoming an important issue in self-care. Chapter 4 discuses a first study, in a Smart Home Lab setting, of a Personal Computer Assistant for troubleshooting of domestic medical instruments. It is integrated in a Troubleshooting Environment, which facilitates interaction with the medical instrument and the Computer Assistant. We evaluated the cooperative and directive feedback styles with younger adults, according to scenarios, on troubleshooting performance. The results showed that the Computer Assistant improved maintenance and troubleshooting of domestic medical instruments. Moreover, the cooperative feedback was more effective and satisfying, whereas the directive feedback is more efficient.

Finally, personal characteristics, i.e., computer experience, education level, spatial ability, reading skills, reading speed, locus of control, and fear of invalidity, explained variance in troubleshooting process and outcomes.

Although findings show that a Computer Assistant can contribute to troubleshooting, occasionally technical failures are of such gravity that the support of a technical specialist is required. Chapter 5 discusses Computer Assistants for remote collaborative troubleshooting. We redesigned the Troubleshooting Environment with Assistants to facilitate remote collaboration and evaluated the influence of cooperative and directive feedback on remote collaborative troubleshooting in a smart home lab setting. The participants were younger and older adults, who according to scenarios played the role of technical specialist and novice patient, respectively. The different feedbacks styles are implemented as follows. The cooperative assistant suggested key sentences, involved the participants in the decision-making process and guided troubleshooting step by step. The directive assistant made autonomous decisions and solely presented instruction to which the participants had to comply. Results showed that collaboration was optimal when older patients receive cooperative feedback and technical specialists receiving directive feedback. Moreover, personal characteristics, i.e., age, computer experience, education level, spatial ability, and locus of control, explained variance in the troubleshooting process and outcomes.

Low medical adherence, i.e., the extent to which a patient's self-care activities matches with medical or health advice, forms an important bottleneck in the care domain. Chapter 6 discusses a Personal Computer Assistant that supports ongoing daily care activities. We designed a Digital Diary with Personal Computer Assistance and evaluated the influence of cooperative and directive feedback on daily care activities by adults at home. Results showed that in relation to performing care activities, participants had a strong preference for the cooperative feedback style, which expressly involved them in setting and executing the care plan. These results imply that the cooperative feedback style is more beneficial for medical adherences and developing health literacy, and could help diabetes patients perform self-care. However, in case of a health critical situation, such as a hyper- or hypoglycemic attack, the directive feedback style could more beneficial.

To address this trade-off, Chapter 7 discusses the design of a Digital Diabetes Diary with Adaptive Computer Assistant, which provides cooperative feedback, but switches to directive feedback in the case of a health critical situation. We evaluated the Adaptive Computer Assistant in a Smart Home Lab with older adults engaged in scenarios reflecting normal and health critical situations. Results showed that the adaptive assistant was more effective in dealing with normal and health critical situations, and, generally, led to more time efficiency. Moreover, the use of the diary led to an increase in diabetes knowledge. Finally, participants indicated the need for mobility and multimodal interaction. Consequently, we designed and evaluated a multimodal Mobile Diet Diary. Results showed that older adults interacting with the diary preferred textual and graphical feedback to textual and speech feedback. For both the home computer and the mobile diary, participants' personal characteristics, i.e., age, spatial ability, working memory, memory span, vocabulary, perceptual speed, and locus of control, explained variance in the self-care process and outcomes.

The previous chapters discuss lab studies depicting that Personal Computer Assistants can be suitable for self-care, concerning troubleshooting of domestic medical instruments and increasing medical adherence. Chapter 8 discusses a randomized controlled trial (RCT) on a Persuasive Computer Assistant that supports overweight persons to perform self-care independently, over an extended period of time. The assistant is represented by an animated iCat, which shows different facial expressions and provides cooperative feedback following principles from the motivational interviewing method. We evaluated the assistant's influence on self-care, i.e., the use of an Online Lifestyle Diary called DieetInzicht.nl with overweight people over a period of four weeks and studied the difference between diary use with and without Computer Assistant feedback. Results showed that the Computer Assistant contributed to filling in the diary more frequently, reduced the decline in motivation to perform self-care, lowered the (reported) Body Mass Index (BMI) and improved the ease of use. Furthermore, diary use increased knowledge of maintaining a healthy lifestyle. Finally, personal characteristics, i.e., locus of control, vocabulary, computer experience, age, gender, education level and initial BMI, explained the variance in the diary use and its outcome. In general, this study shows that the DieetInzicht eHealth service, including a

Computer Assistant, is likely to support motivated overweight people and lifestyle related diseases to get a better insight in and adhere to their self-care.

These findings imply a positive effect of Personal Computer Assistant with different feedback styles and appearance on the challenges with self-care activities. Adhering to self-care objectives, including the use of medical instrument, is a complex issue and dependent on the patient's knowledge, understanding, motivation, which can change per day, and the trade-off between maintaining both a healthy life and a good quality of life. The evaluation of the different Computer Assistants demonstrate that they address these self-care issues by offering support with different feedback and appearances depending on the user, task, context, and Human Factors. The support should be cooperative when aiming at effective and satisfying performance, which is relevant for older patients; directive when aiming at efficient and vigorous performance, which is relevant for experts; adaptive when aiming dynamic support, which is relevant for attending to changing health situations; persuasive when aiming at motivation, which is relevant for sustainable performance.

Moreover, our findings contributed to the field of Human-Computer Assistant interaction. They define different types of Computer Assistant feedback styles and appearance and their effect on personalization, they depict how adaptive interfaces can help attend to dynamic situations, and illustrate the contribution of persuasive technology to set and adhere to lifestyle goals. Also, in line with the theory, we showed how the use of Personal Computer Assistants contributes to the tailoring of eHealth services across populations, diseases, and situations. Finally, our findings can be applied in other domains, such as the naval, space and police domain, which deal with complex situations and demand high level attention from various actors.

In conclusion the use of Personal Computer Assistants contributes to the personalization of eHealth services. In turn, the enhancement of eHealth supports self-care activities, such as self-monitoring and medical adherence. Performing these activities, undertaken in collaboration with caregivers, families and communities with the intention of preventing disease, limiting illness, and restoring health, makes it possible to increase patient satisfaction and alleviate the burden on current health care services.

SAMENVATTING

Er treedt een verschuiving op van een patiënt die eenzijdig zorg ontvangt van de zorgverlener naar een meer onafhankelijke, zelfbewuste en actieve houding waarbij de nadruk ligt op het behalen van zelfzorg doelen. Dit is van groot belang bij het toenemende aantal mensen met chronische en/of levensstijlgerelateerde ziektebeelden, zoals diabetes type II en overgewicht. Door het toepassen van Informatie en Communicatie Technologie (ICT) in de zorg kunnen eHealth diensten zelfzorg stimuleren. Bovendien kunnen, net als bij het SuperAssist model waarbinnen computer assistenten gepersonaliseerde steun bieden, Persoonlijk Computer Assistenten bijdragen aan de verbetering van eHealth diensten. Toch is er weinig empirisch onderzoek naar de vraag hoe eHealth diensten met Persoonlijk Computer Assistenten zelfzorg kunnen ondersteunen en wat de effecten daarvan zijn. Als gevolg hiervan hebben wij onderzoek verricht naar hoe bepaalde kenmerken van de Persoonlijke Computer Assistent eHealth diensten kunnen verbeteren en zelfzorg kunnen ondersteunen. Het gaat hierbij om het troubleshooten van technische problemen bij medische instrumenten bij de patiënt thuis en om therapietrouw aan zelfzorgdoelen. Onze aandacht lag op de invloed van de kenmerken feedbackstijlen en presentatie op zelfzorg processen en uitkomsten. We hebben gekeken naar twee Assistent feedbackstijlen, namelijk coöperatief, dat coachend en onderwijzend is en zich richt op grote mate van betrokkenheid van de gebruiker met het oog op lange termijn capaciteit, en directief, dat instruerend, rapporterend is en zich richt op het volgen van instructies met het oog op het snel oplossen van problemen.. Ook hebben we naar verschillende Assistent presentaties gekeken, namelijk tekst, afbeeldingen en animatie avatars. Tot slot hebben we bestudeerd hoe persoonskenmerken, zoals gebruiker, omgeving en instrumenten en Human Factors, zoals demografische kenmerken, cognitieve capaciteiten en persoonlijkheid, variatie in zelfzorg verklaren.

Hoofdstuk 2 handelt over de toepassing van de Cognitive Engineering (CE) aanpak voor de ontwikkeling van eHealth diensten met Persoonlijke Computer Assistenten. Deze aanpak heeft bewezen succesvol te zijn op andere gebieden die, net als de zorg, te maken hebben met complexe situaties waar gemakkelijk fouten kunnen optreden en die een hoge mate van aandacht vergen van verschillende actoren met verschillende behoeften. De aanpak begint met een analyse van het medische werkdomein en van technische ondersteuning. Het gaat om zelfzorg, Human Factors en toekomstige technologie. Vervolgens worden de analyse-uitkomsten gebruikt voor het opstellen van ontwerpspecificaties betreffende functies, claims en scenario's. Deze specificaties worden gebruikt om in Smart Home Laboratoria en in veldomgeving interactief onderzoek te doen naar het effect van Persoonlijke Computer Assistenten met verschillende feedbackstijlen en presentatie op zelfzorg. .

Een voorwaarde om de voorgestelde Persoonlijk Computer Assistenten op grote schaal te kunnen implementeren in eHealth diensten is dat het technisch uitvoerbaar is. Hoofdstuk drie gaat hierover en bespreekt het ontwerp en de kwalitatieve evaluatie van een eHealth raamwerk met Persoonlijke Computer Assistenten. Met als uitgangspunt de basisfuncties en scenario's van het SuperAssist project hebben we een digitaal diabetes dagboek met Persoonlijk Computer Assistent ontwikkeld dat is gebaseerd op een Multi Agent Systeem (MAS). Vervolgens hebben we geëvalueerd of het raamwerk van meerdere gedistribueerde agenten, die optraden als onafhankelijke intelligente actoren en als Persoonlijke Computer Assistenten, leidde tot gebruiksvriendelijk beheer van medische gegevens. De resultaten toonden aan dat de ontwikkeling van een eHealth raamwerk met Computer Assistent technisch mogelijk is. Bovendien konden de verschillende menselijke- en computeractoren via het dagboek eenvoudig persoonlijk medische gegevens beheren. Het besproken raamwerk is gebruikt voor volgende experimenten.

Er worden steeds meer medische instrumenten in huis gebruikt voor patiënt-zelfmonitoring. Hierdoor spelen onderhoud en het oplossen van technische problemen, oftewel troubleshooten, een steeds grotere rol bij zelfzorg. Hoofdstuk 4 bespreekt het eerste onderzoek in een Smart Home Lab naar een Persoonlijke Computer Assistent voor het troubleshooten van medische instrumenten thuis. De Assistent is geïntegreerd in een Troubleshooting Programma dat interactie tussen de gebruiker, het medische instrument en de Assistent mogelijk maakt. We hebben de invloed van de coöperatieve en directieve feedbackstijlen op troubleshooten met studenten geëvalueerd aan de hand van scenario's. De resultaten toonden aan dat de computer assistent bijdroeg aan onderhoud en troubleshooten van medische instrumenten thuis. Bovendien was de coöperatieve feedbackstijl effectiever en leidde tot meer tevredenheid en de directieve feedbackstijl was efficiënter. Tot slot bleek dat de persoonskenmerken computerervaring, opleidingsniveau, ruimtelijk inzicht, leesvaardigheid en -snelheid, locus of control en fear of invalidity de variantie verklaarden in het troubleshootproces en -uitkomst.

Hoewel onze bevindingen aantonen dat een Persoonlijke Computer Assistent kan bijdragen aan troubleshooten zijn sommige technische problemen van een dusdanige aard dat ondersteuning van een technische helpdesk vereist is. Hoofdstuk 5 bespreekt een Computer Assistent voor gezamenlijke troubleshooten van technische problemen die voor komen bij medische isntrumenten thuis. We hebben het Troubleshooting Programma herontworpen voor gezamenlijk troubleshooten op afstand en de invloed van coöperatieve en directieve feedbackstijlen op troubleshooten geëvalueerd in een Smart Home Lab. De deelnemers waren studenten en ouderen die aan de hand van scenario's de rol van respectievelijk technische specialist en onervaren patiënt speelden. De feedbackstijlen zijn als volgt geïmplementeerd: de coöperatieve assistent gaf voorbeeldzinnen, betrok de gebruiker in het beslissingsproces en begeleidde hem of haar stap voor stap door het troubelshootingsproces. De directieve assistent maakte autonoom beslissingen en presenteerde troubleshootinstructies die de gebruiker moest opvolgen. De resultaten toonden aan dat samenwerking optimaal was in het geval dat de patiënt coöperatieve en de technische specialist directieve feedback kreeg. Bovendien werd de variatie in het troubleshootingsproces en de uitkomsten verklaard door de persoonskenmerken leeftijd, compturervaring, opleidingsniveau, ruimtelijk inzicht en locus of control.

Een lage therapietrouw, de mate waarin de zelfzorg activiteiten van patiënt overeenkomt met het zorgadvies, vormt een aanmerkelijk probleem in de zorg. Hoofdstuk 6 bespreekt een Persoonlijke Computer Assistent voor de ondersteuning van dagelijkse zorg activiteiten. We hebben een digitaal dagboek met Persoonlijke Computer Assistent ontworpen en de invloed van coöperatieve en directieve feedback op de zorg geëvalueerd met ouderen vanuit hun thuissituatie. De resultaten toonden aan dat de deelnemers wat betreft het uitvoeren van zorgactiviteiten, een voorkeur hadden voor de coöperatieve feedbackstijl die betrokkenheid van de gebruiker vereiste. Dit impliceert dat deze feedbackstijl de voorkeur krijgt bij de ondersteuning van therapietrouw en het ontwikkelen van medische kennis en kan bijdragen aan zelfzorg. Daar staat tegenover dat in geval van kritische situaties, zoals een hypo- of hyperglycemie aanval, de directieve feedbackstijl beter is.

Hoofdstuk 7 behandelt dit dilemma en bespreekt het ontwerp van een digitale diabetes dagboek met Adaptieve Computer Assistent. De assistent geeft coöperatieve feedback maar wisselt naar directieve feedback in het geval van een kritische situatie. We hebben de Assistent geëvalueerd in een Smart Home Lab met ouderen aan de hand van scenario's die normale en kritische situaties beschreven. De uitkomst hiervan was dat de Adaptieve Assistent effectiever was bij de ondersteuning van beide situaties en over het algemeen tot meer efficiëntie leidde. Bovendien leidde het gebruik van het dagboek tot een toename van medische kennis. Tot slot gaven deelnemers aan dat zij behoefte hadden aan mobiliteit en multimodaliteit. Daarom hebben we een multimodaal mobiel dieetdagboek ontwikkeld . Bij de evaluatie van dit dagboek kwam naar voren dat de ouderen de voorkeur gaven aan tekstuele en grafische feedback boven tekst en spraak. Voor zowel het dagboek op de thuiscomputer en op de mobiele applicatie bleek dat variatie in zelfzorg proces en uitkomsten werden verklaard door de persoonskenmerken leeftijd, ruimtelijk inzicht, werkgeheugen, langetermijngeheugen, vocabulaire, perceptueel vermogen en locus of control.

De voorgaande hoofdstukken bespraken het onderzoek in het lab met als uitkomst dat Persoonlijke Computer Assistenten de zelfzorgtaken troubleshooten en therapietrouw kunnen ondersteunen. Hoofdstuk 8 bespreekt een randomzied controlled trial (RCT) onderzoek naar een Persuasieve Computer Assistent dat ondersteuning biedt voor zelfzorg aan mensen met overgewicht over een langere periode. De assistent bestaat uit een animatie iCat die verschillende gezichtsuitdrukkingen toont en coöperatieve feedback biedt aan de hand van het motivational interviewing principe. We hebben de invloed van de Assistent op zelfzorg, dat wil zeggen het gebruik van een online levensstijldagboek DieetInzicht, geëvalueerd met mensen met overgewicht gedurende vier weken. Resultaten toonden aan dat de Persuasieve Computer Assistent leidde tot frequenter invullen van het dagboek, afname van motivatie voor zelfzorg tegen ging, zelfgerapporteerde BMI verlaagde. Ook verhoogde het het gebruikersgemak..Daarnaast zorgde het dagboekgebruik voor een toename van medische kennis. Tot slot bleek dat de gebruikerskenmerken leeftijd, geslacht, opleidingsniveau en BMI variatie in het zelfzorgproces en in de uitkomsten verklaarden. Over het algemeen bleek uit het onderzoek dat de eHealth dienst DieetInzicht met Computer Assistent kan bijdragen aan inzicht in en therapietrouw aan zelfzorg door gemotiveerde mensen met overgewicht.

Deze bevindingen impliceren een positief effect van de Persoonlijke Computer Assistenten met verschillende feedbackstijlen en presentatievormen op de uitdagingen van zelfzorg. Therapietrouw en het gebruik van medische instrumenten thuis zijn complex en hangen sterk af van de competentie om het onderhouden van een gezonde levenstijl te kunnen combineren met het genieten van een goede kwaliteit van het leven. De evaluatie van de verschillende Computer Assistenten bewijst dat die de benadering van deze zelfzorgproblematiek kunnen ondersteunen door het bieden van verschillende feedbackstijlen in presentatievormen afgemeten op de gebruiker, de taak, context en de Human Factors. De ondersteuning moet coöperatief zijn in het geval van een effectieve en voldoeninggevende aanpak, directief bij een efficiënte en doortastende aanpak, adaptief in het geval van dynamische ondersteuning, en persuasief in geval van langdurige motiverende aanpak.

Verder dragen onze bevindingen bij aan het Mens-Computer Assistent Interactie domein. Zij definiëren verschillende feedbackstijlen en presentatievormen en hun effect op personalisatie, tonen aan hoe adaptieve interactie kan bijdragen aan de afstemming van computerondersteuning op dynamische situaties en illustreren hoe persuasieve technologie kan bijdragen aan het stellen en navolgen van persoonlijk levensstijldoelen. Ook hebben we aangetoond hoe, in lijn met voorgaand onderzoek, Persoonlijke Computer Assistenten kunnen bijdragen aan het afstemmen van eHealth diensten op verschillende doelgroepen, ziektebeelden en context. Tot slot kunnen onze bevindingen toegepast worden op andere werkterreinen, zoals marine, ruimtevaart en politie, die te maken hebben met complexe situaties en vragen om een hoog aandachtsniveau van de verscheidene actoren.

Het gebruik van Persoonlijke Computer Assistenten draagt bij aan de personalisatie van eHealth diensten. Daarom ondersteunt deze een verbetering van eHealth zelfzorgactiviteiten zoals zelfmonitoring en therapietrouw. Het uitvoeren van deze activiteiten in samenwerking met zorgverleners, familie en vrienden, met het oog op het voorkomen en limiteren van ziektebeelden en op herstel maakt het mogelijk de tevredenheid van de patiënt te vergroten en de huidige last op de zorgverlening te verlichten.

ACKNOWLEDGEMENTS

I would like to acknowledge and express my gratitude to the following for their significant contribution to my education and the writing of this dissertation.

First, all my colleagues with whom I worked at TNO, in Soesterberg, and who contributed to my education in Human Factors. Specifically, I would like to mention my supervisor Mark Neerincx for his guidance over the course of my dissertation process. He showed me the true value of iteration. Jasper Lindenberg for his many interesting and creative scientific design ideas. Rosemarijn Looije for all her groundbreaking work on the iCat, from which the SuperAssist project has greatly profited. Marc Grootjen and Jan Willem Streefkerk, I would like to thank you both for our many interesting scientific discussions and acknowledge the friendship that grew out of our mutual fun and challenging PhD experiences. In addition, I want to thank Wilfried Post for introducing me to applied scientific research. It is a lasting contribution to my work.

Also, I want to thank my colleagues at TNO Leiden, who recently gave me a warm welcome in the Care Innovation group and were an inspiration during the finalization of my dissertation. Specifically, I would like to mention Laurence Alpay and Wilma Otten for their refreshing perspective on assistance for self-care. Furthermore, Adrie Dumay for introducing me further into robotics in health care.

Second, I would like to express my gratitude to my former colleagues at Delft University of Technology (DUT), who contributed to my academic development. I want to thank the people at the Human-Machine Interaction group (MMI), at the department of Electronic Engineering, Computer Science and Mathematics (EWI). Specifically, I want to mention Charles van der Mast for guidance during my dissertation research and his helping hand in supervising students. Catholijn Jonker for her lively and involved feedback during the presentations of my work. Huib de Ridder, at Industrial Design, for our interesting discussions on interpretation of my research results. Also, I want to express my gratitude to the students who contributed to my studies with their impressively designed eHealth services. I want to wish you all the best in your further professional lives. Specifically, I want to thank, Miroslav Bojic, Nicola Cappiello, Lennard Kuijten, and Vanessa Sawirjo.

Third, I want to thank Emiel Krahmer's contribution to my academic education during my gradation thesis at the University of Tilburg and as dissertation commission member.

Fourth, I want to thank the people who hosted me during my internship at Georgia Tech University in the Fall of 2006. I had an immensely inspiring time at the Human Factors and Aging Lab. I want to thank Wendy Rogers and Dan Fisk for augmenting my research methodology experience and Anne McLaughlin for providing a place to stay and facilitate a smooth arrival. Also, I want to thank the people at the AwareHome, who helped me set up my study. Specifically, I would like to thank Brian Jones, from GVU.

Fifth, I want to thank the people at Clinical Information Research (KIK), at the Leiden University Medical Center (LUMC), who directed me in the health care service and ensured the medical relevance of my research. Specifically, I want to thank Bertie Schonk and Amy Ahluwalia. Also, I want to thank Paul van der Boog, who showed me the ins and outs of health care in practice. Furthermore, together with Hannie Piels, he was very kind in letting us use their lifestyle diary DieetInzicht, which enabled us to evaluate eHealth with Personal Computer Assistants in the field.

Sixth, I want to thank the people at IOP-MMI for financially contributing to the SuperAssist project and offering the possibilities to position our work on multiple occasions. Also, I want to thank the supervising commission (begeleidingscommissie) for their feedback on our research on eHealth with Personal

Computer Assistants. Specifically, I want to thank Rene Collier and Boris de Ruyter.

Seventh, I want to thank JanWillem, Dullaert, Aerend, Van Ramshorst and Melle, from Plexus Naribus, for keeping me in key with life outside of science. Furthermore, I want to thank Lennart Kleinen for supporting me by being my ceremony master. In addition, Aard Bakker for his stellar design of my dissertation book. It really became a work representative of its content, despite his toilsome times.

Eighth, I want to thank my dear family members for their ongoing support, interest and commitment to my research. Barbara, for lending her expertise in Dutch grammar. My siblings, Sander, Iris and Marleen, for making my down time with them so rejuvenating and fun. Maurits for his support and his pride when describing my work to others. I greatly appreciate both. Florence for her ongoing confidence in my abilities throughout my education. This has always meant so much to me.

Most of all, I want to express my infinite gratitude to Andrea, my beloved partner, for all her support and empathy during my dissertation. I think, by now, she knows my research better than I, which is not only a sign of great interest, but also of great love.

Finally, I want to thank all the 275 persons, in the Netherlands and the United States, who participated in the lab and field studies. Your participation was key and the studies would not have been such a success and lead to such interesting and significant findings without your time and dedication.

CURRICULUM VITAE

After finishing his VWO at the Hervorm Lyceum Zuid in Amsterdam, in 1999, Olivier Blanson Henkemans (born August 27, 1979 in Amsterdam) began his academic career at the University of Tilburg. He completed his degree in Communication and Information Science in 2004, after writing his thesis at TNO Human Factors on a research environment for eliciting meeting behavior. This enriching study, in which natural user behavior could be studied in a controlled environment, enthused him to continue his career as a researcher. At this point he began his PhD on Personal Computer Assistants for Self-Care at Delft University of Technology, department of Electronic Engineering, Computer Science and Mathematics (EWI) and in collaboration with TNO Human Factors. During his PhD research, he looked at how different Computer Assistant's feedback styles and representations can contribute to troubleshooting of domestic medical instruments and adhering to self-care objectives by different users, in varying contexts, with the use of multiple eHealth services. To augment his research development, he did an internship at Georgia Tech, in the Fall of 2006, at the Human Factors and Aging Lab and the Aware Home Research Initiative. After finalizing his PhD in 2008, Olivier continued his work on eHealth services for the Patient Empowerment Group at TNO Quality of Life. Here, his focus is on ICT support for patients to gain insights in their own health condition, make informed and valued decisions about self-care activities, and create coaching strategies to assist patients in attaining and maintaining personal goals while adhering to self-care activities in their daily life.