NeuroCare – Personalization and Adaptation of Digital Training Programs for Mild Cognitive Impairments

Sandro Hardy[1], Christian Reuter[1], Stefan Göbel[1], Ralf Steinmetz[1], Gisa Baller[2], Elke Kalbe[2], Abdelkarim El Moussaoui[3], Sven Abels[3], Susanne Dienst[4], Mareike Dornhöfer[4], Madjid Fathi[4]

[1] Technische Universität Darmstadt, Multimedia Communications Lab (KOM), Rundeturmstr. 10, 64283 Darmstadt

[2] Universität Vechta, Institut für Gerontologie, Psychologische Gerontologie & Center für Neuropsychologische Diagnostik und Intervention (CeNDI), Driverstr. 22, 49377 Vechta

[3] Ascora GmbH, Birkenallee 43, 27777 Ganderkesee,

[4] University of Siegen, Institute of Knowledge Based Systems and Knowledge Management (KBS), Hölderlinstrasse 3, 57068 Siegen

Abstract: Changes of cognitive and physical skills are a fundamental aspect of normal aging, but these personal skills fundamentally influence the quality of life and independency of a person. This is even more critical when the changes are decreasing in an above-average or even a pathologic manner. Keeping an individual's cognitive skills at a certain level is therefore an individual as well as a societal goal. Accompanying the demographic change, however, the number of people with Mild Cognitive Impairments (MCI) rapidly increases. One intervention approach for the stabilization of the personal skill level and a deferment of possible further degradation are specialized cognitive and physical training programs. In order to increase the effectiveness and efficiency of such training programs, concepts for the adaption and personalization of such systems constitute the focus of the scientific discussion. In this publication, a new approach for the realization of digital dementia screening as well as technological solutions for the creation of adaptive and personalized training systems are presented. These approaches and solutions build the basis for the scientifically founded creation of effective and user-centered cognitive training modules within the research project NeuroCare, funded by the German Federal Ministry of Education and Research.

Introduction and Motivation

The diagnosis of dementia and the medical intervention at an early stage are strongly demanded nationally and internationally. Today, only 12% of the MCI-patients [8] and 51% of the people with early dementia [15] are recognized by doctors. Accordingly, there is a great demand for easily available cognitive screening instruments that can be used in doctor's offices as well as hospitals, nursing houses for the elderly, and at home by potential patients.

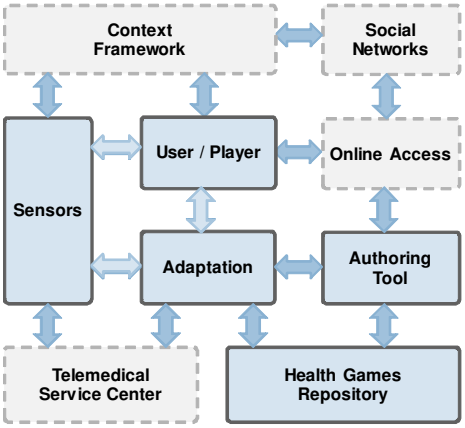

Fig. 1. General architecture for adaptive personalized training systems based on [5]

First approaches exist, but are not common in clinical praxis. Holistic concepts and recommendations for patients and relatives based on the screenings are also lacking. Non-pharmacological as well as neuropsychological-therapeutic approaches for dementia are moving in the focus of scientific discussion [4] but it is fundamentally agreed that the actual evaluation results are still insufficient – standardized and dementia-level-dependent programs and randomized, controlled clinical studies are still lacking [17].

The approach presented in this paper is based on the holistic concept for the technology assisted creation, adaptation and assessment of motivating physical training programs shown in Fig. 1, which is an extended version of an application context model for exergames [5]. The main idea is to create a set of Health Games according to the requirements of different domains with the help of an authoring tool which integrates mechanisms for the adaptation and personalization of the games. These games are then stored in a so called "Health Games Repository". For a specific user, the appropriate game is taken and adapted according to assessments before and during the gameplay in real time. A telemedical service center is an optional possibility to assist the usage of the system and to allow manual adaptation. Information retrieved from a context framework might improve the adaptation process as well [7]. The connection of Social Networks allows the interchange with other users and the access of an online system can provide addi-

tional information, not only to the end user themselves, but also to their social environment. The possibility of integrating user created content by using an online authoring system can increase the curiosity and diversity of provided exercises.

Background and Related Work

The main challenges are the practical realization of scientifically founded and effective training methodologies for mild cognitive impairments, to fulfill the therapeutic requirements from dementia research, the development of technological methodologies („NeuroCare-Trainer“, „NeuroCare-Assistant“) for the cost-efficient creation, adaptation and personalization of training programs („NeuroCare-Configurator“) and the provision accompanying information for users and their relatives („NeuroCare-Portal“). Therefore in this chapter we sum up the requirements from the domain experts as well as technical approaches of configuration and authoring tools and information portals.

A major goal of NeuroCare is an early detection of dementia. This is supported by the „first screening“-procedure. This first screening is available for interested people worrying about themselves and having the feeling that they may be impacted in their cognitive capacity. As a second target group, family members may want to check the cognitive capabilities of relatives for negative impacts preemptively. The first screening process is the entrance to the NeuroCare system and therefore accessible from the NeuroCare-Portal, which represents the first contact in the use of NeuroCare.

The first screening is conceptualized by neurological experts und consists of a succession of tests that check the cognitive capabilities of the user. For this purpose, the user is supposed to solve the tests sequentially and anonymously. Afterwards, the user receives a statement (dependent on his results) about his estimated cognitive constraints.

An additional screening procedure is provided by the NeuroCare-Assistant. This assistant is (unlike the first screening) only available for registered NeuroCare users and it has to be repeated at several specific times. The assistant consists of many tests that challenge a specific part of the brain (memory, attention, executives, space cognition and language). These tests have to be solved multiple times and are afterwards send to the backend of NeuroCare in an encrypted way. This allows NeuroCare to realize a training which reacts to the strengths and weaknesses of each user. Those tests are referred to as a „test battery“ in NeuroCare.

For the creation and rapid prototyping of story- or process-oriented applications such as training programs or educational games, the authoring framework StoryTec is one of the leading technologies [11].

To support the easy creation of interactive application without programming skills and without deeper knowledge of technology, devices or platforms, StoryTec contains a well-elaborated template system in combination with so-called “expert views”. This allows the specialized support of domain experts from the

diverse application fields. This system also contains support for collaborative authoring processes [12] as well as the configuration of games in the area of health prevention and rehabilitation [6].

In NeuroCare a portal is planned as an interface for interested users to discover information about the project itself and the NeuroCare modules to support caregivers of dementia patients. A portal is an application that is realized based on web technology; it offers a central access to personalized content and processes as needed [14]. Portals which focus on a specific topic are called vertical portals and medicine portals take a place in this category. These medical portals like the NeuroCare-Portal are focused on topics around healthcare and medicine [2], in this case cognitive impairments and dementia. Typically they provide different content from information about diseases and expert search to live recordings from surgeries [2]. In the field of dementia various portals like "Alzheimer.de"[1], "Wegweiser Demenz"[2], "Alzheimer Wissensportal"[3] exist. The internet usage of the target group (50+) increases as well, with the application fields of learning, information search, online buying and networking [9]. The technical realization of portals is often done by Content Management Systems (CMS). Web CMS are used for management and distribution of information [3]. Their main advantage is an easy publication of content and only few requirements about programming knowledge in daily use.

Approach and Concept

The specific architecture for the NeuroCare project consists of four different modules contributing to the overall system (Fig. 2). The process chain of the NeuroCare system starts with a MCI-screening within the NeuroCare-Portal or the NeuroCare-Assisstant. As a result of the screening a cognitive skill rating for the user is provided. Based on this assessment data a recommendation is provided, which might, if necessary, contain the advice to consult a doctor and/or to start cognitive training. This training contains modules which are created by experts using the NeuroCare-Configurator. The NeuroCare-Configurator offers the ability to implement fine-grained adaptation mechanisms which adapt the difficulty of the training modules according to the training progress of the user, keeping him at an optimal training load. Based on the pre-configuration, the adaptive game engine adjusts different parameters at runtime i.e. while the user is training.

[1] http://alzheimer.de

[2] http://www.wegweiser-demenz.de

[3] http://www.alzheimer-wissensportal.de

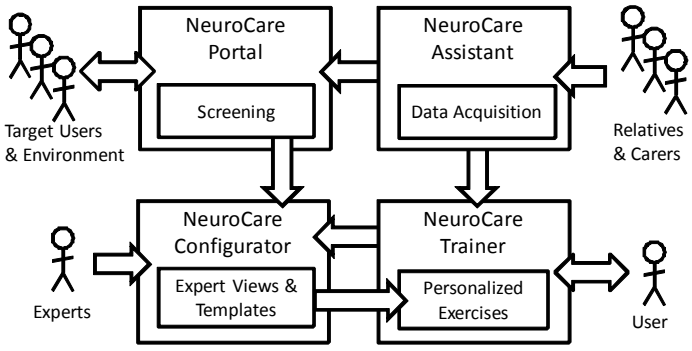

Fig. 2**.** NeuroCare Modules and Interfaces

The training results and the progress of the user are recorded and stored in the NeuroCare-Backend to allow their doctor to monitor the training. A special focus of the NeuroCare project is the inclusion of the social environment of the users. Relatives as well as caregivers can retrieve specialized information from the NeuroCare-Portal and gain assistance by using the NeuroCare-Assisstant. In the end, the approach and concepts developed within the project NeuroCare will be assessed regarding suitability for daily use, technical feasibility and ethical issues. While these aspects will be discussed and documented in detail during the project, they are not included in the technical focus of this paper.

NeuroCare-Portal

The NeuroCare-Portal provides a starting point into NeuroCare, offering functionalities for exchanging information or communicating with other affected and interested persons like their caregiver. Thereby a special challenge is to provide the information multilingual and to give recommendations geared to specific target groups. Within the scope of the project the following realization areas are detected and addressed:

The public area of the NeuroCare-Portal should offer information about dementia, care at home or other related training issues. The content is multilingual with a focus to the languages of German, English, Turkish and Russian, thus addressing people with a migration background in Germany as well. A well-structured design and navigation provides an easy way for finding the right content. A public forum is aspired for exchanging topics, discussion points and questions around the diseases and the care situation. For being up-to-date about new developments, group appointments or other aspects, a newsletter function is planned.

Next to the content of the portal and its newsletter function, news about NeuroCare will be published via official Social Media channels like Facebook or

Twitter. For the simultaneous publication in the different channels a special middleware is to be incorporated [10].

Via a login function, the user will be able to access the private area of the portal. The login information is identical for all features of NeuroCare thus offering the users easy access to all features (e.g. NeuroCare-Assistant or Trainer). Based on the target group of MCI or starting dementia patients, it is possible to link an account of a (family) caregiver to the account of the patient, thus making it more convenient for the care situation. For communication of patients and (professional) caregivers, an internal social network is integrated into the portal. This way it will be possible for the family caregivers to get in contact with other persons in a similar situation or to receive remote help from a medical professional. Different contact functions are incorporated like sending direct messages, chat, blogs, exchanging contacts or creating a group. Every function is explained with an additional text, thus making it user friendly. The user profile itself is different for patients, family caregivers or people working professionally in the care sector. The user may decide which information is made public for the network or used for recommendation functions inside the network. The recommendation function recommends not only content, but also persons or groups related to the current user situation or search request.

For enhancing the other NeuroCare modules, the user may upload media data like photos via the internal area of the Portal. This personal media, as well as the content and the profiles are stored in the NeuroCare-Backend. For organizing a group meeting or a public event, a calendar function is part of the portal. The user may decide to add these appointments to their personal calendar.

As already mentioned in the introductory part, the NeuroCare-Portal is the entry point for all NeuroCare modules. Accordingly the portal offers information about all NeuroCare modules as well as e.g. a trial version of the NeuroCare Trainer, screening as part of the NeuroCare Assistant, training courses of NeuroCare LeMo or AAL services for the care at home.

For the realization of the NeuroCare-Portal , the CMS Drupal[4] will be applied. The technology has been chosen after a structured requirement analysis at the first stage of the project. The middleware for publishing content in different social media channels is named SoCom [10]. The internal social network will be realized via an open source social networking engine, which has also been selected based on a formal requirements analysis. It will be integrated in the Drupal realization. For storage of all content and profiles the NeuroCare backend will be used.

NeuroCare Assistant

The NeuroCare-Assistant supports caring relatives and caregivers in the execution of the screening in cooperation with the impaired person. As of today, most

[4] https://drupal.org/

screening processes are still realized based on paper and pencil. In contrast to this, NeuroCare provides a very simple and intuitive digital procedure to acquire and process screening results. This process is easier to use, since the impacted person does not need to physically move to an establishment for performing the screening processes. Instead, the user may perform the screening at home together with a family member or caregiver. The process is designed to work intuitively, because the whole screening process runs as an application on a tablet PC and consequently provides familiar gestures (like touch, wipe and move) with a low barrier of entrany. Another advantage of the NeuroCare-Assistant is the rapid processing of captured data during the screening session. Whereas the paper and pencil version produces a heap of papers that must be processed from the experts and stored in archives that will gradually grow, the NeuroCare-Assistant fetches only relevant data from the whole screening procedure, processes it digitally on the basis of computer logic developed by experts and stores the results distinctly into a main storage at the NeuroCare-Backend. This way the results of every screening session will be available for doctors or caregivers in order to look at the progress in case for which they are authorized to do so.

The NeuroCare-Assistant interchanges data via the backend with other NeuroCare components like the NeuroCare-Trainer, the Configurator and the Portal. The aim of this data exchange is to enable these components to use the results achieved by executing the screening. For example the tasks of the NeuroCare-Trainer have to be adapted to the current cognitive capabilities of the patient. Those are captured by the NeuroCare-Assistant during a screening session and passed to the backend so that the NeuroCare-Trainer is able to adapt its task difficulty to the cognitive status of the user according to the performance during the training.

NeuroCare Trainer

The NeuroCare-Trainer is a cognitive training instrument for personalized training at home or in geriatric facilities. It consists of a six-week program with three lessons per week (18 units in total), each of them has a duration of about 40 minutes. Three variants of the training exist depending on the individual's cognitive state. The assignment to one of three difficulty levels is based on a cognitive profile assessed with a digital neuropsychological test battery (i.e. the NeuroCare-Assistant) which classifies whether a person's performance indicates "age-adequate cognition", "possible mild cognitive dysfunction", or "cognitive impairment". Training elements which are individually tailored to this assessment are: psycho-education explaining important knowledge about the aging brain, lifestyle factors influencing cognitive functions and explanation of cognitive compensational strategies, cognitive exercises and recommendations for everyday life ("daily tip for promoting cognition") as well as individual feedback on training success. The program is adaptive so that the level of difficulty in cognitive exercises changes based on the individual levels of performance. A comprehensive database

of stimulus material enables repetitions of cognitive exercises with new items each time time the training is processed.

Individuals without cognitive impairments can use the program independently with different choice options in regard to the selection of the exercises and training intensity. Individuals with cognitive impairment scan be supported by their relatives or medical staff and are guided through the training in a well-structured way that is easy to follow. For patients with clear cognitive impairments, the program also offers facilities to do biography work.

The NeuroCare-Trainer is different from other existing programs in the way that it is specifically designed to enhance cognition in aging subjects without and with cognitive impairment and that difficulty levels are directly related to the levels of performance indicated above. Furthermore, the NeuroCare-Trainer offers psycho-education that is again matched to the topic of cognitive aging and cognitive impairment in senior patients. The efficacy of the basis of the program, the already existing non-digital group programme NEUROvitalis [1], has been evaluated in scientific studies (Petrelli et al., under review).

NeuroCare-Configurator

The NeuroCare-Trainer as well as the learning modules created for the project will be implemented using the NeuroCare-Configurator, which is based on the authoring tool StoryTec [11]. This approach offers several advantages. On the one hand, the tool can be used by authors without programming skills, who are then able to edit the training or learning modules on their own. This allows them to update the content of these modules immediately without the need for programming support. Possible users are neurologists who want to modify the training based on evaluation results or other new scientific results in their field. On the other hand, even expert users can use the tool to implement the modules more quickly, speeding up the process while also making it cheaper.

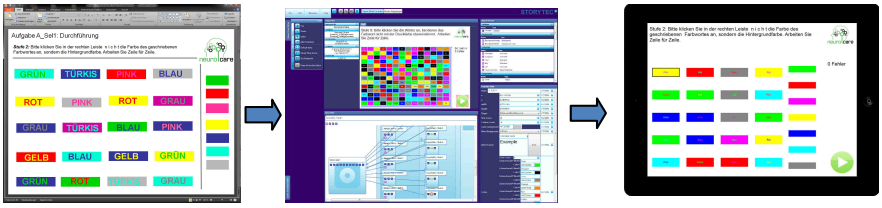

Fig. 3. Authoring Workflow: Concept, Configurator and Application

The decision to use an authoring tool resulted in the following development process: In order to allow the configuration of complex user interactions like the individual practice units from the NeuroCare-Trainer, these interactions must be implemented as templates first. For this step, a textual description provided by the subject matter experts (here: neurologists) is separated into constant and variable

aspects. While the basic task definition (e.g. “click all items with a specific color”) is fixed, other aspects (e.g. the number of items presented to the user) are kept variable. This allows authors to change these variables later easily and without the need to know the exact technical implementation of the user interaction template [13].

After these templates are created, the modules can be implemented by non-programmers completely. Their basic structure is created first by defining screens (scenes) and how the user is able to navigate between them (transitions). This task is often done by media designers, i.e. experts on how a specific content should be presented to the user. These designers also define the general “look & feel” of the module by adding fonts and graphical elements to the scenes. This basic structure is then set to read-only in order to prevent accidental modifications in later steps.

After that, subject matter experts are able to insert the previously defined interaction templates into the scenes and change the variables connected to them at will, for example to offer different levels of difficulty for a single practice unit. They are also able to add further multimedia elements like texts, images or videos, which can be used in order to explain the tasks to the players.

When a module is defined completely, it is exported to be playable by the users – in this case, patients with mild cognitive impairments. Since the export-function was built for cross-platform-support, the modules can be realized as native iOS or Android-Apps and work in web-based or PC-based (HTML5) settings as well.

Additionally some of the training tasks are designed to include personal information from the patient’s past, which is meant to be inserted by their relatives or caregivers. This is done via a web-based version of the NeuroCare-Configurator, which is able to insert information into the training module after it is exported. For security reasons the web-based version is restricted to specific information marked as editable by the designers or subject matter experts and provides only a subset of the functions provided by the configurator used during development. Since the nature of the authoring tools makes it easy to change the module created with it, an iterative development process is supported. When early usability tests for example showed that the font was too small when viewed on tablets, the designers where able to update the module quickly.

Summary and Outlook

The demographic change increased the demand for solutions, which allow early diagnosis and alleviation of age-related decrements of cognitive and physical skills. In this publication approaches for the creation of personalized and adaptive training systems for these skills as well as their integration in the social environment of the end users are presented. Within the research project NeuroCare, these concepts and approaches will be implemented and evaluated together with end-users. This way NeuroCare provides an essential contribution for the research in the field of human-technology-interaction.

Acknowledgments

We would like to thank the German Federal Minity of Education and Research for funding this research in the project „NeuroCare - Ganzheitliches Konzept zur Unterstützung und Entlastung von ambulanten Pflegekräften und Angehörigen bei der Betreuung von kognitiv beeinträchtigten Senioren“ in the field of Ambient Assisted Living.

References

1. Baller, G. et al.: NeuroVitalis. Neuropsychologisches Gruppenprogramm zur Förderung der geistigen Leistungsfähigkeit. Prolog (2010).
2. Bärwolff, H. et al.: IT-Systeme in der Medizin, IT-Entscheidungshilfe für den Medizinbereich - Konzepte, Standards und optimierte Prozesse. Vieweg & Sohn Verlag, Wiesbaden (2006).
3. Bodendorf, F.: Daten- und Wissensmanagement. Springer-Verlag, Berlin/Heidelberg (2006).
4. Buschert, V. et al.: Cognitive intervention in Alzheimer disease. Nat. Rev. Neurol. 6, 9, 508–517 (2010).
5. Göbel, S. et al.: Serious Games for Health: Personalized Exergames. Proceedings of the International Conference on Multimedia. pp. 1663–1666 ACM, New York, NY, USA (2010).
6. Hardy, S. et al.: Adaptation Model for Indoor Exergames. Int. J. Comput. Sci. Sport. 11, Edition 1, 73–85 (2012).
7. Hardy, S. et al.: Context Aware Serious Games Framework for Sport and Health. 1–5 (2011).
8. Kaduszkiewicz, H. et al.: Do general practitioners recognize mild cognitive impairment in their patients? J. Nutr. Health Aging. 14, 8, 697–702 (2010).
9. Kampmann, B. et al.: Birgit Kampmann Michael Knippelmeyer Frank Wagner (Hrsg .) Die Alten und das Netz Angebote und Nutzung jenseits des Jugendkults. Gabler Verlag | Springer Fachmedien, Wiesbaden (2012).
10. Konert, J. et al.: Towards Social Serious Games. In: Thomas Connolly Patrick Felicia, G.N.S.T. (ed.) Proceedings of the 6th European Conference on Games Based Learning (ECGBL). Academic Bookshop, Kidmore End, Nr Reading, UK (2012).
11. Mehm, F. et al.: An Authoring Tool for Educational Adventure Games: Concept, Game Models and Authoring Processes. Int. J. Game-Based Learn. 3, 63–79 (2013).
12. Mehm, F. et al.: Collaborative Authoring of Serious Games for Health. Proceedings of the International Conference on Multimedia. pp. 807–808 ACM, New York, NY, USA (2011).
13. Mehm, F. et al.: Introducing Component-Based Templates into a Game Authoring Tool. In: Dimitris Gouscos, M.M. (ed.) 5th European Conference on Games Based Learning. pp. 395–403 Academic Conferences Limited, Reading, UK (2011).
14. Möbus, C. et al.: Web-Kommunikation mit OpenSource. Chatbots, Virtuelle Messen, Rich-Media-Content, Xpert.press. Springer, Berlin, Heidelberg (2006).
15. Pentzek, M. et al.: Apart from Nihilism and Stigma: What Influences General Practitioners' Accuracy in Identifying Incident Dementia? Am. J. Geriatr. Psychiatry. 17, 11, 965–75 (2009).
16. Petrelli, A. et al.: (under review) Effects of neuropsychological training in Parkinson's Disease: a cluster randomized controlled trial.
17. Report, W.A.: The benefits of early diagnosis and intervention World Alzheimer Report 2011. (2011).