Digital technology-enabled home health care

requirements of successfully delivering home-based interventions. In addition, future studies should investigate the optimal levels, dosage, duration and timing of cognitive training in PD. We think that in the human brain, there is room to maintain cognition and autonomy for longer periods of time if training is started as soon as the first symptoms arise, or preferably even sooner. Due to functional brain plasticity, we also believe that the human brain is physically capable of shifting functions to other brain regions or circuitries, thereby helping to maintain cognitive function. We doubt whether cognitive training can ever restore cognition to pre-clinical levels when it is already significantly declined, but progression to dementia is not inevitable [11] and this should be a target on the horizon.

Further innovations will improve cognitive training elements by making it smarter (AI), more tailored (gamification) and potentially more generalizable to real life (exercise and/or VR), which usually is a disadvantage to functional cognitive training. In the ideal scenario, cognitive functions can be trained for longer periods of time by an array of cognitive therapies that transfer improvements into a real-world setting, so that a patient experiences the true success of the therapy.

One day, innovations will enable patients to have various home-based interventions to be personalized, attractive, precise, and efficient, all at once.

POTENTIAL IMPACT OF THIS THESIS

SCIENTIFIC RELEVANCE

Digital technology in health care empowers healthcare professionals to deliver care to patients' homes, thereby making them less dependent on hospitals or nursing homes. The research presented in this thesis adds to the knowledge of both the feasibility as well as the efficacy of digital technology-enabled cognitive training in an elderly population, with a focus on gamification. In the scientific community, researchers can benefit from our feasibility results to improve adherence in future studies. First, our results suggest that it might be important for researchers to assist research subjects in planning their intervention activities, by creating a personalized training schedule. Second, elderly may require more time to familiarize themselves with digital interventions and this process might initially be in need of guided training sessions. Third, the addition of pro-active remote support, in which subjects are contacted on a frequent basis about their therapy progression, may further enhance adherence to the treatment. By following these guidelines, researchers might additionally prevent dropout due to a mismatch between research requirements and patients' capacities to follow those expectations.

In the ideal scenario, cognitive functions can be trained for longer periods of time by an array of cognitive therapies that transfer improvements into a real-world setting, so that a patient experiences the true success of the therapy. Gamification is all about engagement. Patients

that are engaged to a therapy are first and foremost more likely to complete the treatment plan, but they also have a greater shot at experiencing the beneficial effects introduced by the therapy, such as living independently at home for longer. From a scientific perspective though, there still is a lot to learn about specific elements in gamification that promote the attainment of effective skills the most.

Our resting-state fMRI meta-analysis provides additional evidence for the association between cognitive decline and reduced connectivity in the default node network in PD, this was suggested by other researchers as well (**Chapter 2**). Therefore, our results may provide additional support for continued research in this area, and this potentially results in a future biomarker for cognitive decline in PD. Finding a valid biomarker for cognitive decline could provide new opportunities for early detection of cognitive decline, and consequently may also yield timely intervention of this decline, which is suggested to be more beneficial as compared to intervention later in the disease. Gained knowledge in this relatively new territory may also provide insights in new biological targets for cognitive rehabilitation, which could then be targeted with improved-adherence interventions.

POTENTIAL FOR HOME-BASED CARE

In addition to its relevance in research, the gained knowledge in this thesis can be particularly relevant for both caregivers and health care in general. Even if patients are receiving interventions without gamified elements, caregivers should consider the adherence-promoting strategies that were presented in this thesis, such as active (human) support throughout the use of the platform as well as tailoring of the platform to the user's competences, as assessed by a digital assessment (**Chapter 5**).

In addition, the vast majority of health care is still delivered in a traditional hospital setting. The cost of delivering certain types of health care to the patients' homes could be significantly lower. Due to home-based health care, patients can start better managing their own health and wellbeing. Digital home-based health care can also act as a prevention measure to hospital or nursing home admissions and limit readmissions to hospitals or nursing homes [22]. Moreover, in the midst of cross-border health threats like (corona)viruses, hospitals and nursing homes can become high risk settings for those who are more vulnerable to infections. Hereby, digital and home-based interventions are more indispensable than ever by decreasing the risk of infections. During pandemics, digital tech-enabled home care benefits hospital resources management in a couple of ways. Firstly, less staff capacity is required to deliver care to patients in a hospital setting. Secondly, less infections mean more capacity in the nursing wards and Intensive Care units for those who need it. Thirdly, gamification elements can be used to enhance knowledge and application of certain infection prevention procedures by caregivers as well as patients [23].

Further, in health care, gamification could be added as compliance-increasing elements to other target groups and contexts, for example, therapies for psychological disorders,

physical training, or even medication management. Yet, can our research, and gamification in particular, serve a purpose beyond the context of health care? Gamification can have an impact in other contexts as well, and I think both education and business can especially benefit from lessons learned here.

GAMIFICATION IN EDUCATION

Our current educational system contains some flaws, in my opinion, that are potentially at the basis of increasing disinterest and boredome among students. Firstly, one of those flaws is group size. Instead of tailoring courses to the individual abilities and interest of its pupils, teachers are generally teaching large, 30-person groups with generic courses. Yet, researchers have found that people dislike activities that are too easy or too hard [7], which means that this impersonal educational practice could lead to pupils switching off during classes. Secondly, the school system seems to be focused on prestige instead of failure: successful tests are rewarded with good grades, yet unsuccessful tests are considered a failure and are awarded low grades. Although trial and error is an extremely efficient learning concept, in the classroom, low grades are given for failed attempts, thereby discouraging students to keep trying. NASA did not reach space on its first shot, but kept trying and eventually landed a human being on the moon by learning from earlier "failed attempts". NASA's goals were reached not in spite of failing, but due to learning from failure [24].

These flaws in our educational system could be addressed with gamification strategies by making learning a more fun experience. For example, digital courses with gamified elements could tailor the classes to the individual students, despite group size. Also, additional courses could be added for those students who show particular interest in certain aspects. Furthermore, awarding students' progression with progress points after completing educational objectives assists them to track progress and encourage perseverance. Trial and error could be emphasized in gamified courses through awarding learning points, as an alternative for low grades, that could provide proof of a students' effort to reach a certain goal. I believe that institutions could improve the overall learning experience by adding gamification elements.

GAMIFIED BUSINESSES

Gamification could be used to boost business results as well. By implementing gamified elements like goals, achievements, rewards and leaderboards, gamified platforms could engage employees to more effectively track their work progress and subsequently promote action-taking behavior in order to succeed in business [25]. Employees that use gamified platforms may outperform others, with an increase return on investment as a result. A gamified cognitive training could more specifically increase the cognitive load limit of businessmen, for example by improving focus and thinking speed, thereby optimizing performance.

RECOMMENDATIONS FOR THE SERIOUS GAMES INDUSTRY

While developing new treatments, creators in the industry can use our results to create games that are more suitable for elderly target groups, for which they can use our recommendations specifically tailored at PD patients, as presented in **Chapter 3** and **4**. Facilitators and barriers for treatment adherence should be addressed, such as patient-related, therapy-related, health care related, and disease-related factors. Another important consideration should be the introduction of a larger variety of training elements and levels in order to prevent boredom in the patient group. Moreover, a bottom-up design approach should be followed in which the industry, patients, researchers and caregivers collaborate to develop motivating therapies that can be executed in the home environment.

TECHNOLOGICAL AND SOCIETAL READINESS

The technology readiness level (TRL) scale was first used by NASA in the nineteen-seventies as systematic maturity assessment of a technology during its development, from idea generation to commercialization [26]. TRL is a nine-step ordinal scale (with 9 being the most mature) that is widely accepted as critical in making development decisions and investments for new technology. For good reason, it is used as a tool to evaluate both the potential and progression of European Horizon 2020 innovation projects [27]. Our gamified home-based cognitive intervention for PD has already completed TRL levels 1 to 4, which means that the technology concept has been formulated and the proof of concept have been developed and completed. We consider our technology to be at TRL 5 or 6, indicating that the technology has been validated and demonstrated in a relevant population (PD) from a feasibility perspective, but the innovation still needs to be adjusted and efficacy needs to be proved in the real life setting.

Since the TRL focusses solely on the technological aspects of a project, the societal readiness level (SRL) was designed as an alternative scale to assess the societal adoption readiness of an innovation. The SRL is a nine-step ordinal scale and gives an impression of the steps required for a successful transition towards societal adaptation (as designed by Innovation Fund Denmark). SRL levels 1-3 reflect the work that was presented in this thesis, in which we included relevant stakeholders and target groups in the design process and we additionally identified the current base for gamified interventions in PD. SRL levels 4-6 have also been implicitly included in this thesis by forming and testing our research hypothesis as well as researching the impact of our product in the target group. SRL level 7 is the next step: our product needs to be refined and the subsequent results need to communicated to create awareness among relevant stakeholders in order to complete societal adaptation.

COMMUNICATING RESEARCH TO THE PUBLIC

Proper communication of scientific results to potential target groups is often overlooked in research. An essential requirement of a PhD program is the writing of scientific manuscripts to be published in scientific journals. This means that, with the correct search words and the right subscription, the results can be found by an academic audience through scientific search engines. Talks at specific conferences are also common ways of disseminating results to that

audience. Research that is published in high impact journals may receive additional attention from regional or national news networks. When in luck, novel research will be picked up by the international press, which increases the likelihood of knowledge finding the appropriate audience. In addition to scientific publications, it is also common practice to translate scientific results into simpler language in order to inform the subjects that were included into studies. Nevertheless, scientific progress in cognitive training might be of interest to other audiences as well, such as caregivers (medical or psychological), businesses, the serious games industry, and the general public.

In line with the digital context of this thesis, I think it would be appropriate to follow a combined offline and online approach in communicating this research to the relevant stakeholders. Firstly, patients could be informed through patient associations via both newsletters and presentations. Secondly, a press release should be written as a short and appealing summary of the research. Thirdly, web-based, online media could be contacted in order to speak about this research in webinars and podcasts. Fourthly, conferences with a focus on eHealth, health care technology, and (neuro)psychology should be addressed and attended in order to reach an academic audience. Lastly, digital health tech blogs should be contacted to write a column about the investigated topic as well as the potential impact of the results.

Through these steps, I believe that we have a fair shot at conveying the prerequisites of gamification in home-based health care to relevant audiences, that can use this knowledge to their advantage in the future.