

Intelligent Toys For Physical And Cognitive Assessments

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IMPACT PARAGRAPH

In this addendum, a reflection is presented on the scientific impact of the conducted research in this dissertation as well as the social impact anticipated or already achieved (University (2020)). The proposed intelligent game devices and their applications have enormous social and economic interests in the current society and the future. This paragraph addresses the drafted four research questions in the given regulations (University (2020)), which are related to the main objective of the research and its relevance, target group, and activity.

Research: *“What is the main objective of the research described in this dissertation, and what are the most important results and conclusions?” (University (2020))*

In the dissertation, we study the value of combining algorithms from data science and artificial intelligence with robotics to assess the well-being of humans, and more specifically elderly and children. At the moment, the number of instruments available for assessing the well-being of these target groups is limited. There is however a strong need for assessment instruments that allow for long-term continuous assessments of physical and cognitive capabilities of elderly and children. Such instruments should require little effort from caregivers and teachers and that can be used continuously during daily activities such as play. The intelligent assessment devices, Instrumented Activity Dice and Intelligent Maze, that we develop and evaluate and have the potential to fulfill the aforementioned requirements. As demonstrated in this thesis, these intelligent game devices allow the assessment of cognitive and physical capabilities during play.

Monitoring and assessing the capabilities in the elderly is important to detect possible deficits and maintain their quality of life. Assessments for early detection of ailments and interventions are one of the means by which we can ensure the continued quality of life for the elderly. The assessments are also required for predicting if therapy or treatment is required and if the treatment is improving their condition. But without the use of technology, such tests for the assessment of well-being and physical performance can be a tedious process and no fun for the participants or the caregivers.

Monitoring and assessing the capabilities in children is important to ensure and track their healthy development and identify potential deficits. These tests are also important for establishing a norm to make peer comparisons in skill development (Brown and Jernigan (2012)). With these assessment devices, we continuously obtain large amounts of data about the players that we process to infer their capabilities.

The main objectives of the research in this dissertation are as follows:

- **Avoiding stressful testing for elderly and children in artificial test environments.**
- **Embed assessments within games so that assessments are more enjoyable for the participants.**

- **Making assessments more objective and precise, saving time and expertise investment.**

The proportion of people of working age in the EU-28 has been and keeps shrinking. The relative number of people estimated to be aged 65 or older and thus being retired or expected to be retired soon has been expanding by 2.4% over the past ten years (Christopher and Möckel (2021a)). As a greater proportion of the post-war baby-boom generation reaches retirement in the coming years and due to the consistency of fewer births in the past year, professional projections predict that people aged 65 years or over will account for 29.1% of the EU-28's population by 2080, compared with 19.2% in 2016 leading to a continuously growing demand for more caregivers for elderly (Christopher and Möckel (2021b)).

Already now, there is a lack of available caregivers. At the same time, the demand for documentation and quality management increases and thus reduces the time caregivers can spend on the work they love: providing care for the elderly and children. Instead, facilities for the elderly and children report that caregivers must spend up to 50% and more of their time on documentation and management tasks. This results in frustration for caregivers and high costs for the caregiving facilities, health insurance, and society.

Similarly, as caregivers, also teachers at schools and kindergartens face the challenge that assessments of children and especially its documentation, for instance, in the form of certificates, take a lot of time – time that teachers would prefer to spend instead on teaching. At the same time, schools in the Netherlands face a lack of teachers. In June 2017, a shortfall of some 900 primary school teachers was reported with the prediction that these numbers would further increase in the future. The number of people qualifying as primary school teachers has fallen from some 7,300 in 2005 to around 3,800 in 2015 (Times (2020)). So it becomes more and more crucial to unload teachers from tedious assessment and documentation work to spend their time more effectively – but also to make their work more attractive again.

The execution of psychological and physical tests is typically stressful both for the elderly and children when being assessed (Fleege et al. (1992)). To avoid uncontrollable influences, the elderly and children often are typically separated from their natural environment. Still, the test results are not objective and have the risk of being dependent on the skills of the experimenter (Chaytor and Schmitter-Edgecombe (2003)). Continuous testing becomes difficult because of time constraints, is often too expensive, and there is a risk that elderly or children are not tested at all for deficits that are not already sufficiently expressed, with the risk that treatments come too late.

Often these tasks also require extensive scoring after the test. The process, therefore, requires high time and expertise investment from the examiner. Given the large time and expertise investments needed, large-scale implementation of such assessments is therefore difficult to realize.

From the studies conducted in this dissertation, we concluded that it is indeed possible to assess cognitive and physical capabilities using intelligent game devices. The studies in chapter 4 and 5 showed the potential of using an intelligent toy, the Instrumented Activity Dice, for assessing the physical performance of people playing with the Dice. The studies in chapter 6, 7 and 8 showed the potential of using the second intelligent toy introduced in this thesis, the Intelligent Maze, for assessing the cognitive capa-

bilities of children playing with the Maze. The assessments in both intelligent toys were done automatically by the game devices, and hence no manual scoring was required after the assessment. Children reported to have fun while playing with the Intelligent Maze. Caregivers, teachers, and researchers observed that elderly and children enjoyed playing together with the Intelligent Activity Dice. Hence the studies conducted in this dissertation concluded that the intelligent game device designed with the principles of stealth assessment and automatic data extraction does make the assessments more enjoyable and objective, saving time and expertise investment. Since the assessments are automated, the high documentation load for the caregivers and teachers is also reduced. The caregivers and teachers need only participate in the games and provide help where needed.

Relevance: *“What is the (potential) contribution of the results from this research to science and, if applicable, to social sectors and social challenges?”(University (2020))*

The research in this dissertation aims at contributing to improving the existing methods of assessment. The potential benefits to the vulnerable population and society at large are immense. Each of the proposed game devices presented in this dissertation improved the physical and cognitive assessment of children and the elderly. The novel method of data collection for assessment can also be extended to other games that the elderly and children play. This rationale is also related to the concept of stealth assessment (Shute and Ventura (2013); Shute et al. (2016, 2010)), in which performance data is gathered during learning in a playful way from games and toys. Another advantage of using such intelligent game devices is the adaptability and modularity of such devices. The Instrumented Activity dice can be extended to include as many and as complex games as needed. The type of activities can also be changed for the Dice. The same holds true for the Intelligent Maze. The Maze can be extended to include more maze patterns or other games that can be incorporated in a board. The potential use of these game devices with other such intelligent toys can provide a comprehensive and holistic insight into the cognitive and physical capabilities of people. The continuous collection of data on children especially can provide valuable insights into developmental trajectories. If sufficient toys in a classroom or caregiver facility are smart, such as mazes, dolls, blocks, and so on, a comprehensive view of cognitive and other skills may be possible. The natural behavior of the person can unfold without a teacher or caregiver testing the person in a one-to-one setting.

Continuous and objective quality assessments in the long run also allow for better quality control through the management. Moreover, caregivers and teachers having more time for the elderly and children leads to higher efficiency and lower costs for the facilities and, in turn, health insurance. Earlier and better detection of required treatments for the elderly profoundly reduces costs in caregiving facilities and health insurance. Furthermore, by providing objective, long-term data, health insurance can obtain better information about the effectiveness of the applied therapies and treatments. Besides, more efficient caregiving contributes to a reduction of the economic load faced by society because of the surge of the aging population.

The novel data collection for assessment presented in the Intelligent Maze in this

dissertation has successfully automated the data extraction process accurately by about 99%. This means that the Intelligent Maze can reduce the workload of data collection of teachers by at least as much as 99%, showing great potential. The novel assessment method of using Intelligent Activity Dice shows that the device can extract physical performance metrics that would otherwise require the use of cameras or bodily sensors.

The studies conducted in Chapters 4, 5 and 6 have been published in various conference proceedings. At the beginning of each chapter, the papers which are parts of the corresponding chapter are listed. The studies conducted in Chapters 7 and 8 are being prepared to be published to journals.

Target group: *“To whom are the research results interesting and/or relevant? And why?”(University (2020))*

The primary target groups of the studies conducted in this dissertation are the elderly, children, teachers, caregivers, and researchers in the field of cognitive and physical assessments, serious games, human-computer interaction, and social robotics. Moreover, these applications are of great interest in our societies with a tremendous social and economic impact. There are various benefits to the elderly and children who play with these game devices.

By playing games continuously, it is possible to obtain objective data on the capabilities of the elderly and children continuously, over a long time, and more often per day than it would be possible if caregivers or teachers had to provide the information through observation. And as the intelligent game devices prove, the automation of data collection is possible with about 99% accuracy. As a result, there is higher quality and more objective data to support a better choice of treatment or therapy. The need for treatments or therapies can be detected earlier. Unnecessary treatments can be avoided. The quality of life for the elderly and children can be improved. The elderly and children enjoy playing with the game devices and do not realize that they are being tested. In contrast to normal artificial standardized tests, assessments using the game devices cause less stress for the elderly and children – leading to more realistic, higher-quality assessments in natural environments.

The caregivers and teachers also benefit immensely from the research in this dissertation.

Activity: *“In what way can these target groups be involved in and informed about the research results so that the knowledge gained can be used in the future?”(University (2020))*

Throughout the research and studies conducted in this dissertation, we have tried to perform collaborative, embedded ethics (Stahl and Coeckelbergh (2016)) which directly and substantially involves end-users in innovation and user processes. The caregivers and teachers have been involved in the design process of the game devices and have given valuable inputs and feedback in the iterative design process. We have tried to be ethically and socially responsible by involving the stakeholders in the innovation process and have had the caregivers test the various versions of the game device with the elderly.

Moreover, the game devices presented in this dissertation were used by the target population during the studies. The Instrumented Activity Dice has undergone several

beta testing with the elderly population and caregivers, and the valuable feedback from the caregivers has been used for further improvement of the Instrumented Activity Dice.