Serious games as a level playing field for early literacy

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Summary

This thesis reports upon the creation and evaluation of a literacy digital game-based learning tool for beginning readers of Dutch. Across languages, 10-15% of children fail to attain standard reading levels, making early detection and rehabilitation of existing and potential reading problems a worldwide mission (OECD, 2014). In addition to a genetic component in the manifestation of reading problems, letter knowledge, phonological awareness, rapid automatised naming and verbal working memory are behavioural precursors of reading proficiency. A poor performance in any of these domains poses a cognitive risk during the ongoing development of literacy skills. Intervention studies show that an extensive training these exact skills with struggling readers helps them in becoming more accurate and fluent readers, which in turn inspired further research into preventive interventions at the onset of literacy instruction in school, or even kindergarten. At the same time, the emergence and availability of computers, smartphones and tablets in families and education systems around the globe have led to an exploration of digital tools to support reading instruction in a wide range of settings. While many studies have delivered literacy training with the help of computer games in a wide variety of languages, there is inconsistent evidence regarding their effectiveness, ranging from a big proportion of training resistors and no relevant gains, up to lasting improvements in terms of reading fluency and accuracy. Such contradictive results are often attributed to cross-linguistic differences in the consistency of writing systems. However, within this growing body of research, there are many more variables at play which may affect the outcomes of such a training. These could relate to target populations in terms of age and selection criteria, to training characteristics like game content, the intensity and frequency of playing, as well as interactions of these factors. Another open discussion point is how to accurately assess training effectiveness by means of psychometric tests, in-game data, or even using neurophysiological measures like electroencephalography in the first place.

Chapter 1 provides an introduction to key concepts and results of previous research, leading to the research questions which are then addressed by a series of studies related to a game-based literacy training in beginning readers of Dutch. These questions are as follows:

1. What are the short- and long-term effects of a six-week-long computerized literacy training at the start of first grade in Dutch?

2. Which children benefit from such training?

3. How do training properties modulate training outcome, and are there any interactions with population properties?

4. Can data gathered during game-based learning help to overcome limited test sensitivity to changes in reading and reading related skills?

5. Are training improvements reflected in auditory and visual processing as indicated by electroencephalographic responses?

Chapter 2 gives an in-depth explanation of the development of a literacy training program and a very similar mathematics game suitable for Dutch first graders. For the reading game, this process includes a presentation of relevant properties of writing systems as well as current methods of reading instruction in the Netherlands. Furthermore, this chapter explains the intended use case, which leads to number of design choices with regards to the training materials and their order of introduction into the gameplay, which allows the formulation of a level design outline. The chapter continues with a presentation of the general game mechanics and features, and different types of mini-games available within our newly created version of the Dutch GraphoGame and concludes with a detailed introduction of the purpose built in-game assessments to gauge skills such as letter knowledge, counting and written lexical decision with single-trial accuracy and response time measures.

Chapter 3 presents a randomized controlled trial of the Dutch GraphoGame at the onset of formal reading instruction in first grade to evaluate the immediate effects of a cross-sectional training of 287 children from 16 mainstream classrooms in the Netherlands and Belgium. The chapter explores possible impacts of population properties such as familial risk of dyslexia, gender, multilingualism, handedness and poor pre-test scores, as well as training properties like game exposure and game progress on the training outcomes. The training is conducted with an active (arithmetic computer training) and a passive (non-playing) control group during September to December of first grade. Children play for up to seven weeks and undergo behavioural as well as in-game assessments directly before and after the training phase. We uncover unexpectedly big differences in terms of pre-reading skills between the Belgian and Dutch children, ultimately giving even more breadth to our sample. On the short term, exposure to the Dutch GraphoGame improves letter knowledge for children with poor pre-test scores, and it speeds up responses to letters in children with good pre-test letter knowledge. Furthermore, there is a

positive impact on reading fluency for girls who played the reading game extensively and had above average phonological awareness skills at the onset of playing.

Chapter 4 investigates changes in print tuning – the specialisation of the visual cortex to process written text - due to exposure to the Dutch GraphoGame. A subset of 36 children of the study reported in Chapter 3 undergo neurophysiological recordings to evaluate whether our computerized literacy training changes the neural processing of written text in beginning readers towards the brain pattern seen in more fluent readers. This chapter also investigates the potential impact of the target population on training effects by analysing a rather heterogeneous sample of children. Conventional analyses point to the presence of print tuning at the group level and a slight increase in amplitude over training irrespective of gaming condition. A more advanced nonlinear mixed modelling approach also reveals changes of the N170 due to gaming condition. These changes are opposite to our expectations as print tuning becomes less prominent in children exposed to the reading game.

Chapter 5 describes changes in auditory discrimination capabilities due to exposure to the Dutch GraphoGame. A slightly different group of 36 children in the study reported in Chapters 3 and 4 is exposed to an auditory oddball paradigm measuring discrimination performance of spoken syllables. The discrimination contrasts include changes of vowel and consonant quality, as well as vowel duration. Similar to Chapter 4, the sample is rather heterogeneous, which enables us to explore possible brain-behaviour interactions across a broad range of reading abilities with nonlinear mixed models. The results point to the existence of both, big maturational changes in auditory cortical responses which are unrelated to the gaming phase, as well as smaller changes which are attributable to our two gaming conditions. Most importantly, this chapter describes a strong relationship of phonological awareness skills with the late discriminative negativity following vowel changes, absent in other contrasts and has not been described previously.

Chapter 6 investigates long term effects of our computerized literacy training by follow-up assessment of reading fluency and phonological awareness skills. A subsample of 76 children from the Dutch cohort who previously played the reading or the math game is assessed once more at the end of second grade, 1.5 years after the initial training period reported in Chapter 3. Furthermore, this chapter explores the value of in-game training characteristics as an early and concurrent predictor of reading fluency in comparison to conventional predictors such as letter

knowledge, phonological awareness and rapid automatized naming. At follow-up there are no long-term effects in terms of reading fluency or phonological awareness skills associated with the kind of training. However, the training characteristics extracted from a few hours of gaming prove to be very good predictors of concurrent and long-term reading fluency, comparable to data gathered with formal psychometric testing like letter knowledge, phonological awareness and rapid automatized naming.

Chapter 7 brings together the main findings of the four experiments described in Chapters 3 through 6. Here, the effectiveness of the Dutch GraphoGame, which was evaluated with pencil and paper, in-game assessments and neurophysiological measurements, is summarized in relation to the goals established above: possible short- and long-term effects, population and training characteristics, and issues with regards to assessment tool sensitivity. This chapter also presents additional game-related data as a starting point to discuss prospective research, possible extensions to the game content and the exploration of the different kinds of data which game-based learning provides.