Here's Looking at You, Player
The Potential of Eye Tracking Analysis for Player-centered Learning Game Design

Susanne Friedemann, Katharina Meier and Klaus P. Jantke
Fraunhofer Institute for Digital Media Technology, Children's Media Dept., Erich-Kästner-Str. 1a, 99094 Erfurt, Germany

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Abstract: There is no doubt that technology enhanced learning, in general, and game-based learning, in particular, needs thoughtful preparation, a careful design and a reliable implementation to meet the expectations of impact. But e-learning systems and serious games are digital media which usually are perceived very differently by different human learners with individually varying background and experience and within varying contexts. Perception and impact of media are a very delicate issue to be investigated carefully on a firm scientific basis. Digital games designed and implemented for special purposes of learning are particularly difficult to evaluate. Eye tracking is a technology suitable for the analysis of essential features of media perception which are relevant to learning. Eye tracking human learners' interactions with a serious game allows for the detection of substantial phenomena crucial for the design of game playing experiences likely to foster learning processes.

1 THE AUTHORS' POSITION

"Here's looking at you, kid." is a citation from the classic movie *Casablanca* by Michael Curtiz, 1942, starring Ingrid Bergman and Humphrey Bogart. The malapropism "Here's looking at you, User." is due to Christian Wolff[1] in his 2009 lecture on eye tracking in human-machine interaction. For the present paper, this idea has been adopted and adapted to direct the reader's attention to eye tracking of human game play.

The authors' particular focus is on game-based learning (Prensky, 2001). Undoubtedly, play takes a significant place in the development of humans and animals allowing for risk-free exploration and experiment. But contemporary serious games largely fail in meeting the high expectations of game-based learning (see, e.g., (Jantke, 2006a), (Jantke, 2007)). The state of affair is harshly, but felicitously summarized by Simon Egenfeldt-Nielsen in his book on the potential of serious games as follows: "Edutainment started as a serious attempt to create computer games that taught children different subjects. Arguably, it ended up as a caricature of computer games and a reactionary use of learning theory." ((Egenfeldt-Nielsen, 2007), p. 42) There is a necessity to abandon this state of affair.

There is abundant evidence for the need of a wide spectrum of methodologies and tools supporting formative evaluation of the design and implementation of serious games.

The authors' position advocated throughout the present paper is *to employ eye tracking analysis for the improvement of learning systems development, in general, and of serious games, in particular.*

According to the authors' very best knowledge, there is not yet much systematic usage of eye tracking in the process of designing and implementing digital games suitable for serious purposes such as training and learning.

The authors' opinion advocated by means of the present conference contribution relies on a variety of serious games developed and implemented by their team (see, e.g., (Jantke, 2006b), (Gaudl et al., 2009), (Jantke et al., 2009), (Arnold et al., 2013), and (Krebs, 2013) including the usage of eye tracking analysis.

The aim of the paper includes some *exemplified application of eye tracking analysis applied to some serious game project.* There is a number of qualitative questions to be answered.

In the authors' opinion, *the usefulness of eye tracking analysis for player-centered learning game design and implementation can be demonstrated.* This completes the positions to be advocated below.

[1] http://www.uni-regensburg.de/sprache-literatur-kultur/medieninformatik/sekretariat-team/christian-wolff/vortraege

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2 INTRODUCTORY EXAMPLE

In the following example, an eye tracking study on the playing behavior in the serious game “1961” will show how gaze data can provide insights in the very individual as well as common procedures of the players when using a game-based learning application. With the eye tracking system it is possible to follow the subjects’ visual attention on the screen. This allows for a better comprehension of the users’ game play and bears the potential to indicate where and when learning processes may be stimulated.

2.1 Learning by Game Playing

Digital game-based learning unites serious learning and interactive entertainment. This is done by using the fun of gaming for motivating players who get concerned themselves with serious real world problems (see (Prensky, 2001)). The focus is primarily on the real action which is a basis for learning by doing.

In the point & click adventure game “1961” by Anja Hawlitschek completed at Fraunhofer IDMT in 2011, e.g., the player finds himself on some virtual journey back in time to the virtual year 1961 on the virtual Sunday, August 13, in the virtual Berlin when the Berlin Wall was built (Hawlitschek, 2010).

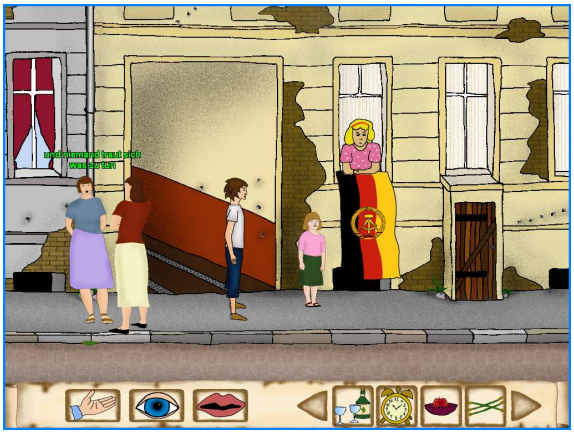

Figure 1: Experiencing life in Berlin in the game “1961”.

What is real in the virtual world of “1961” are the arguments in the virtual characters’ utterances, the problems addressed, and the positions advocated. The virtual world of the game is wrapping the real learning contents (Jantke and Lengyel, 2012).

With the digital game “1961”, the virtual world opens up the player’s access to this time. Virtual conversations of affected people confront players with real problems, arguments, and positions of that time. Different perspectives at the conflict are provided. Accordingly, those conversations are key to learning.

2.2 Didactic Approach

The underlying didactic concept of the game “1961” is based on the model of experiential learning and thus includes self-experiencing and the reliving of events. But for real learning, you need real aspects that are presented in the virtual world. Thus, the players find in “1961”, e.g., virtual original documents such as a newspaper or pictures of that time with real content for a better authenticity complementing the content of the people’s dialogs.

Utterances of virtual characters occurring in the game world of “1961” are designed in such a way that every utterance represents particular contents such as, for instance, a certain social problem, particular economic deficiencies and their impact on daily life, or some political opinion or perspective of that time ((Hawlitschek and Niegemann, 2013), sec. 2, table 1).

The player is not given a specific learning goal, but has a clear game goal, i.e., to find a charged battery to, once more, reach the present (see (Hawlitschek, 2010)). While playing the user gets to know different arguments by the game characters. The true learning contents, so to speak, is presented implicitly and learning is assumed to take place partially unnoticed.

2.3 General Assessment

In general, learning success can be achieved especially based on experimentation, exploration and self-experience. The player gets implicit information about the former “world view” through the virtual communication built on the real arguments of the characters.

First evaluations of the game “1961” investigated usability matters, effectiveness in terms of pedagogical aims as well as game experience and cognitive processes. Positive correlations between motivation and learning success could be reported (see (Hawlitschek and Niegemann, 2013)).

Subsequently, a first exploratory evaluation which was carried out by using an eye tracking system in November 2013 now provides further information on the game design. Adolescents aged from 14 to 16 years who belong to the target group of students attending history classes in secondary school level in Germany took part in the play testing. The exploratory study could benefit from the eye tracking method concerning research questions that considered aspects like, e.g., the decision behavior with respect to the chosen ways to interact with entities, how much time the players dedicate to certain entities, or how entities and dialogs are perceived. Thus, an approximation to understanding gameplay takes place.

2.4 Observations by Eye Tracking

The overall interest of this research is to gather hints *where and how implicit learning in the game "1961" might take place* and how new re-arrangements could help to improve the game-based learning setting. Therefore, the goal of this first and short exploratory evaluation using the eye tracking system was to examine to what extent the test persons follow the factual content and which persons and objects are focused and with which intensity, e.g., by using instruments of fixation count, gaze duration, time to first fixation and scan paths. The focus of the evaluation was on *how dialogs are perceived and under what circumstances they are read by the players.* Therefore, the gaze behaviors of persons who are provided with dialogs were studied. It was of special interest what the players perceived (which objects were focused and how often), which dialogs were requested and how these retrieved dialogs were read (which, how often and how long, which words were focused in which order, e.g. looking jumps and repetitions). Different characteristics could be found and will be described in detail with reference to one exemplary scene.

In the chosen scene (see figure 1 in chapter 2.1) the woman at the window gives information about ways to find the charged battery leading back to the present on the one hand, and about the impact on people's daily lives through the construction of the Wall on the other hand. Furthermore, there is a little girl and two women speaking who are outraged by the construction of the Wall. Some text information are automatically displayed in this scene and thus automatically appear to the player. Other dialogs however have to be actively requested by the user through exploring the characters by clicking on them.

During the exploratory analysis of the eye tracking recordings three different behaviors of handling the dialogs in the game could be observed. The characteristics of the detected ways of text perception are described in the following paragraphs and roughly confirmed in the exemplary excerpt of the data.

Characteristic 1: No Text Perception. Regarding the data, subject 4 did not request any dialog at all in this scene (see figure 2). No interactions except walking around took place. But the eye tracking data confirm that the characters as well as automatically displayed text were fixated several times by this player (see figure 3).

Characteristic 2: Minimum Text Perception. Subject 3 also spent some attention on the characters and texts in this scene. In comparison to subject 4, some further dialogs were chosen to be read additionally, but perceived only in a limited number (see figure 2).

Characteristic 3: High Text Perception. The scene was explored in great detail by subject 1 and 2 what is shown in the high number of clicked dialogs (see figure 2)–and more importantly–in the high number of fixations (see figure 3). In the given example high fixation rates are an indicator of larger numbers of words read by the player what was also confirmed by the scan path analyses.

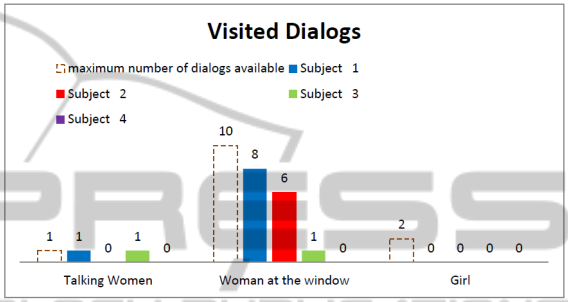

Figure 2: Dialogs retrieved by the subjects (click data).

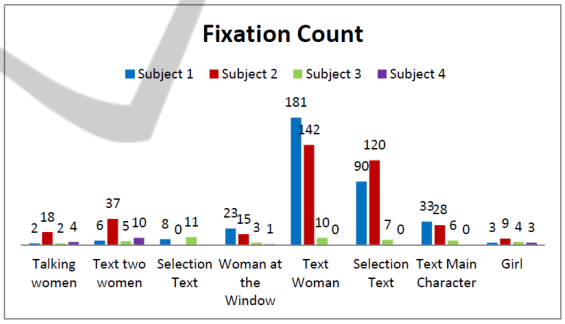

Figure 3: Some differences in attention are visible in the fixation counts (eye tracking data).

Altogether, these different ways of perceiving (additional) textual information detected during the study

- no text perception,
- minimum text perception, and
- high text perception

gave an insight in how several items that are important for achieving learning goals are dealt with. A questionnaire and an interview with the test subjects confirmed the eye tracking findings and investigated some reasons for the playing behavior such as, e.g., a very goal-oriented strategy of subject 3. This led the player to look only for promising information in order to make fast progress in the game–but prevented him from experiencing more interesting details which are part of the learning goals.

In addition, it was possible to show what objects (dialogs, words, objects or persons) had an impact

on the game behavior. For instance, in figure 4 it is shown how single items like words within a dialog can lead into the game world. The scan path in this example demonstrates that stimulus words from the woman's monologue are searched in the game world such as, e.g., "shopping" or "crisis". The objects belonging to these keywords were strongly focused by the subject's eyes and thus gained the necessary attention to become part of a learning process at all. With the eye tracking data it became possible to see, e.g., the order of words read, long lasting considerations or keyword-oriented playing.

Furthermore, the data show that some characters are addressed more often than others, e.g., the test persons did not speak to characters like the girl in the middle of the scene in figure 4, although it has been fixated before by all of the subjects (figure 2 and 3). Changes in game design like animating the girl could open up the contact to this character. Only content gathering attention can become part of implicit learning processes. Eye Tracking supports analyzing where learning becomes possible at all as it shows learners' real actions such as reading and watching which build a fundamental precondition for learning.

Figure 4: The scan path shows how stimulus words lead into the scene.

To sum up, the authors' experiment reported above has been demonstrating that eye tracking works, at least, for purposes such as identifying substantially different behaviors of play which correlate with success or failure, respectively, in perceiving information crucial to human learning to be fostered by the serious game under consideration. Roughly speaking, it turned out, e.g., that players who act too stringently towards success of game play are likely to miss substantial information needed for learning.

The implications for game design and revision are manifold. Insights arrived at by means of such an eye tracking analysis may lead to changes of the game mechanics, to modifications of the visual experience, and to game adaptation to varying styles of play.

3 POTENTIALS OF THE TECHNOLOGY

Game-based learning applications have to fulfill some elementary expectations concerning the user's gameplay experience on the one hand, and didactic intentions on the other hand that might strongly vary from the context of use of a serious game as well as from the user's knowledge, skills and former experiences. In general, eye tracking can help to inspect game play experiences and can also be used, to some extent, to regard and evaluate the impact of didactic arrangements. In this way, it can give feedback to designers and developers of learning games. The short exemplary eye tracking study on "1961" has shown just an entry to reasonable employment of the eye tracking method in the process of serious game development.

Basically, eye tracking is widely known as a technology to uncover usability matters of software applications–very often in terms of website design as it is described by (Nielsen and Pernice, 2010). But there have already been a variety of studies applying eye tracking to digital games as well. This definitely took greater efforts according to the complexity of games as dynamic stimulus, but clearly showed the benefits of eye tracking when evaluating selected game aspects (see, e.g., (Almeida et al., 2011), (Buscher et al., 2010), (Johansen et al., 2008)) that might impact on the player experience. It became possible, for example, to detect preferred watching regions on a screen, unremarkable objects in a game and even differing attentional progresses of inexperienced and hardcore gamers. Furthermore, some attempts were already made to retrace phenomena of game play within exploratory studies like the feeling of immersion or engagement (see, e.g., (Renshaw et al., 2009), (Jennett et al., 2008)), however, still lacking greater examinations, a clear validation of results and systematization of the findings according to intervening variables. Furthermore, it is a highly interesting way to get insights into the interdependencies of game design and the mechanisms of game playing behavior by different users that will enable us to implement didactic concepts in serious games.

After more than one decade of intense eye tracking research some promising novel approaches came up lately that show some first creative enhancements:

Gaze Data Representation. Visualization approaches that allow new insights into the gaze data

will lead to more specific results and also to further questions. For example, illustrations like so-called *space-time-cubes* (Kurzhals and Weiskopf, 2013) directly uncover trends in viewing behavior and sequences of attentional synchrony of several users. *Superimposed 3D scan paths, three-dimensional attentional maps* or *models of interest timelines* (Stellmach et al., 2010) allow detailed multi-perspective inspections of views at 3D environments. At this moment, the exact potentials for examining game play using these techniques are not explored, yet. Nevertheless, even more creative approaches might be needed to face the analysis of those highly individual game play recordings with gaze tracking.

Systematization of Gaze Patterns. Although looks are always depending on the tasks users are performing (see (Nielsen and Pernice, 2010), p. 13 ff. and p. 422 ff.), there are some helpful collections of often shown gaze behaviors, e.g., the so-called f-shape when reading web content. Further existing registers like Ehmke et al.'s *summary of eye-movement metrics related to usability problems* and the derivation of *eye tracking pattern generalizations* (Ehmke and Wilson, 2007) have to be very carefully interpreted because of missing validation, but might give a hint on user's gaze behavior when using websites. Systematized eye tracking in serious gaming contexts could open a wide area of application and make game play experience in manifold cases more comprehensible and, thus, in terms of game-based learning, easier to anticipate.

Feedback on Gaze Patterns. Besides concepts directly using gaze control for steering digital games there are some interesting game input mechanisms like in the prototypically implemented horror-game "Sophia" [2] (status 2013) that uses the *recognition of eye tracking patterns while playing* as a parameter to influence the story and–in this case–to terrify the player by unexpected incidents. Seen from a didactic point of view, concepts like this provide many ideas to implement situations adequate for implicit learning.

Linking Gaze Patterns to Storyboards. In terms of achieving player-centered learning game design, eye tracking might become one key tool (among others) to inspect crucial game sections and create appropriate story alternatives upon the results. This was basically shown in the introductory example on "1961" (see chapter 2) when the progress of attention on learning-relevant objects has been analyzed.Future research by the authors will examine, if and how such findings can be implemented in a digital storyboarding system that allows to anticipate different user-centered learning experiences by means of user modeling and adaptive system behavior. Potentially, eye tracking could contribute to game-based learning scenarios that provide customized didactic patterns underlying a human user's game play–just as he freely explores a scene by playing.

[2]http://www.uni-regensburg.de/pressearchiv/pressemitteilung/302195.html

4 LIMITATIONS OF THE TECHNOLOGY

While eye tracking is already well-known by website developers and is also partly becoming of interest to the video games industry (see, e.g., (Almeida, 2012)) its potentials have not yet been systematically explored and extended to the field of serious gaming. When starting to discuss possible potentials of eye tracking to impact on serious games concepts several limitations have to be considered that underlie several reasons, such as:

- **Technological Limitations**
  - the fact of games being a special case of dynamic 2D- or even 3D-stimuli being controlled by indiviual users and causing individualized data in every session that can hardly be compared one to another,
  - missing automation that helps processing the huge amounts of individual data sets, e.g. in recognizing dynamic areas of interest (AOI) or finding object-dependent patterns in the gaze recordings, as well as
  - a "lack of suitable [analysis] techniques" that help to overcome time-consuming frame-by-frame-analyses like it is described by ((Stellmach et al., 2010)).
- **Methodological Limitations**
  - the necessacity of combining eye tracking data in carefully controlled experiments with additional data by further methods like retrospective thinking aloud-protocols (see, e.g., (Eger et al., 2007)) to extend the information value of the stand-alone-investigations,
  - still missing links in between eye tracking data and further data gathered to describe game play experience (Nacke et al., 2010) like using different methods like questionnaires, interviews, game metrics, psychophysiological player testing etc., and
  - missing validation of gaze patterns described in manifold exploratory case studies such as, for instance,(Ehmke and Wilson, 2007) and (Kivikangas et al., 2010).

To sum up, in order to spread eye tracking as a supporting method in serious game concepting further analysis tools need to be developed to face specific research questions as well as technical challenges, e.g. concerning the comparability of data sets, combination of eye tracking data with data of other sources and creative ways of visualising the gaze data to enable new possibilities of analysis and novel findings.

5 CONCLUSIONS & OUTLOOK

The authors admit that a comprehensive evaluation of "1961" based on eye tracking is still badly missing, to some extent, due to several issues raised in section 4.

The game "1961" has been used to exemplify the way in which eye tracking analysis may lead to some key insights into problems of serious game design. Missing utterances in "1961" is really a crucial issue.

Nowadays, eye tracking still is a costly, but in many fields valuable method to evaluate and support software development. Taking advantage from the eye tracking findings in the area of serious gaming in educational contexts, e.g., for offering individual player experiences or specific didactic approaches, is still open. Systematizing available findings and redefining requirements of eye tracking analyses will help fully exploring the potentials of the technology.

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