Two Decades of Traffic System Education Using the Simulation Game MOBILITY

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Abstract. MOBILITY is a digital simulation game about traffic system planning, which has been designed as a serious game with the purpose of education and awareness raising. Since the year 2000 it has been used more than a million times in both educational and entertainment contexts. The production of digital serious games, such as MOBILITY, requires a lot of effort. Therefore, serious games are valuable investments that are expected to be of high benefit during their technical lifetime. Much has been written about the effectiveness of the use of serious games and efficiency of game production, however later phases of serious games' lifecycles are comparatively unknown. Based on a lifecycle description of MOBILITY, a categorization of lifetime-determining factors called *game aging* is developed. The categorization is intended to serve as methodological framework to guide lifecycle management of serious games, such as assessing the status of a serious game regarding the categories of game aging. Game aging distinguishes three categories: technology, domain knowledge and user experience. For each of these categories the specific characteristics of MOBILITY are described and discussed. Regarding methodology, the evaluations are based on expert interviews, questionnaires and guided interviews. In summary, after two decades of application MOBILITY is still an effective educational tool for traffic system planning, although each of the examined categories shows signs of game aging. Further research is needed to systematize the framework of game aging.

Keywords: Game aging · Software lifecycle · Serious game · Technical lifetime

1 Introduction

The production of attractive and effective serious games requires a lot of effort. Therefore, there is an interest in being able to use serious games as long as possible. Conversely, a long technical lifetime, along with a high number of users and a high impact, is one of the reasons that can justify large development budgets required for the production of attractive and effective serious games. However, the field of interactive media as a subfield of information technology is very fast-moving. This characteristic is diametrically opposed to long technical lifetimes.

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The simulation game MOBILITY can be considered an example of an attractive and effective serious game. It was released in 2000 and has been used more than a million times since then, e.g., it has been successfully used in university courses on traffic system planning. At the same time, it is known from previous work that the simulation game SimCity IV has also been used as an effective serious game for many years. By now, a lot of effort is necessary to provide executable instances of SimCity IV for teaching [1]. The question arises as to how long the technical lifetime of serious games is. Therefore, the determining factors of the technical lifetime of a serious game are also to be investigated.

Profound work on the preservation of computer games, i.e. the possibility to preserve computer games as cultural artifacts for posterity, can be found in the literature, e.g., [2, 3]. In contrast, this paper is not concerned with the problem of making computer games available at all, but rather with problems that arise when games are run in their original application contexts with special regard to affordable effort. It appears that technical lifetime and the later phases of the lifecycle of serious games and factors determining the technical lifetime are not current research topics. Therefore, an initial categorization of factors limiting the technical lifetime of serious games, named game aging, is developed and discussed in this paper using the example of MOBILITY.

The paper is structured as follows: the next section presents MOBILITY, the design of the study and results related to the didactical context. The categories of game aging are then introduced and discussed using the MOBILITY example. Section 4 discusses the results, followed by a summary and conclusions in Sect. 5.

2 MOBILITY

2.1 Lifecycle

This section describes the lifecycle of MOBILITY [4], a simulation game about traffic system planning, as it has proceeded so far. Although the lifecycle is individual, it contains typical characteristics common to other serious games.

Funding and Development. MOBILITY has been developed within a research project funded by the German Federal Ministry of Education and Research (BMBF) [5]. It was released in the year 2000. MOBILITY is based on a monolithic simulation model consisting of 116 variables and 160 causal relations between variables. The development of the simulation model was based on scientifically proven findings. From a technical point of view, MOBILITY is written in C++, without the use of any game engine or other framework. The software company Glamus GmbH was in charge of the development. MOBILITY runs on Microsoft Windows personal computers (PC).

Internationalization. Mobility is available in German and English. Later, Italian was added.

Distribution. At first, 70,000 data carriers with MOBILITY were sold at cost price. Afterwards MOBILITY was distributed via download. Currently, MOBILITY is still available on its homepage [4]. Altogether, the number of short or longtime players is estimated with more than 1 million.

Reception. Mobility has received mostly very positive reviews and has been awarded multiple times. A positive reception in the review of a relevant German computer magazine spurred its proliferation [6]. MOBILITY has been played as an entertainment game without any educational purpose and has been compared to the genre-shaping simulation game SimCity [7]. Thus, in terms of gaming enjoyment MOBILITY was able to compete with SimCity.

Further Development and Maintenance. Shortly after the game's initial release, the necessity to establish a maintenance process became obvious. Shareware fees finance the maintenance process. The functionality of MOBILITY has not been extended since its initial release. However, in 2007 a specific educational package for primary and secondary schools was released based on MOBILITY. It contained localized gaming scenarios (e.g. featuring the German cities of Hanover and Weimar) and supplementary educational resources [8]. An Italian language version was added and MOBILITY was ported to Linux.

Some of the presented characteristics can be considered typical for serious games. Like most serious games, MOBILITY was developed backed by public funding. It is distributed as shareware, which seems to be the currently common business model for serious games. Although a software company manages the distribution of MOBILITY this business model is not sustainable as it does not allow the development of a successor game. At least the maintenance of the game is ensured, which does not seem to be common for serious games. Furthermore, another uncommon serious game feature is the high level of gaming enjoyment that MOBILITY achieves. Altogether, MOBILITY can be seen as a comparatively successful serious game. However, considering the advancing age of MOBILITY and the resulting limitations, the question arises as to at what point of time in its lifecycle MOBILITY will stop working in its application contexts. Thus, in Sect. 3 various aspects of the advancing aging process are analyzed. The analyses are based on a study that is described in the next section.

2.2 Study Design

MOBILITY has been used for more than 10 years in the *Transport Systems Theory* course of the Bachelor's programme in *Environmental Engineering*. *Transport Systems Theory* is concerned with the planning of infrastructure for individual transport, such as streets, and public transport systems, such as bus routes, in urban contexts. In the didactical scenario, students are given a MOBILITY scenario of a city with a dysfunctional public transport system. The task is to analyze the scenario, to collect key performance indicators and to design a public transport system that solves the traffic-related problems of the city. Finally, each student has to submit their resulting MOBILITY scenario including documentation about the solution strategy and achieved values of key performance indicators. The students are prepared in lecture by discussing information about typical problems and appropriate measures (briefing).

The study was carried out as a pilot study on the appropriateness and reception of the chosen design for the didactical scenario. A further research question was concerned with the determination of possible effects attributable to the advanced age of the game software. Table 1 describes the measurements applied in this study. Participation in the questionnaires decreased from questionnaire to questionnaire due to course dropouts and decreasing willingness to participate after completion of the task. The guided interviews were conducted only with students who were available for an interview upon e-mail request.

Table 1. Description of the study's measurements

Measurement	Description	N = …
Questionnaire 1	• Expectancy – value model [9] to assess the general motivation of the students • Pretest to assess the current knowledge before using MOBILITY	9
Questionnaire 2	• EGameFlow [10] to assess the gaming enjoyment directly after playing MOBILITY	6
Questionnaire 3	• Delayed posttest to assess the current knowledge after using MOBILITY • Students' personal estimation of the didactical scenario and its effects	4
Guided interviews	• Interview with students especially about aspects of game aging	5
Expert interview	• Interview with the lecturer about the didactical scenario and MOBILITY	1

2.3 Evaluation of the Didactical Scenario

The evaluation of the didactical scenario was one of the research questions of the study. In the following, the results are presented according to each measurement method.

Guided Interviews. In the conducted guided interviews, participants assessed the overall study task as interesting and motivating in comparison to other study tasks of the course and of the study programme. In particular, however, the relatively short working time required for the study task was highlighted as positive by the majority of participants. Only two participants mentioned gaming experience as motivating. The good introduction to the study task (briefing) was also repeatedly reported as positive in the conducted interviews. The thorough briefing included short training periods that helped participants become accustomed to MOBILITY. Together with the required simulation time of approximately two hours, the average time required to complete the study task was three hours. Interviewees noted critically that the relation between measures and results had to be observed, as is usual for games, instead of being stated explicitly, as in books. Observations, however, take time. Yet, all interviewees were able to remember experiences of learning, e.g., the surprising ineffectiveness of the suburban railway or the necessity to assign the required number of buses to each bus line. This can be seen as an indication of successful learning processes.

Further potential for improvement resulted from the report of one interviewee who stated that due to her strategy game experience she had taken the necessary measures during the first 15 min of the gaming time. Thereafter, she assured herself that the game scenario was also economically balanced and then she left MOBILITY to itself for the rest of the necessary simulation time. In the end, the results required for the study task were achieved and only had to be briefly documented.

Questionnaires. Although questionnaire items identified a high level of social interaction, the didactical scenario could possibly be improved in this regard. The task can be done individually, which does not lead to social interactions that are considered important for learning processes (e.g. [11]).

Pre- and Posttest. Pre- and posttest consisted of five multiple choice questions consisting of a total of 33 options. While the pretest was completed with an average of 60% of correct answers, participants reached an average of 71% in the posttest. The increase of correctness has to be rated as a positive result. However, it is not representative due to the low sample size and the decreased number of participants in the posttest.

Possible Further Developments of the Didactical Scenario. Identified weaknesses of the didactical scenario were the fact that the students played alone, the difficulties in observing cause-effect relationships, and the possibility of being able to reduce the time spent working on the study task and thus to reduce the possible learning time. In order to remedy this situation, it is recommended that the tasks are solved in groups, that players are asked to produce specific extreme effects in MOBILITY, and that a scenario is provided that requires continuous control. In comparison to other tasks of the study programme, the MOBILITY study task could be extended in terms of working time to provide further learning opportunities.

3 Game Aging

The phenomenon of s*oftware aging* has been described by Parnas [12]. He refers to software aging as a phenomenon similar to human aging: *"Old software has begun to cripple its once-proud owners; many products are now viewed as a burden-some legacy from the past. A steadily increasing amount of effort is going into the support of these older products."* He identifies mainly two types of causes for software aging. The first type, the external cause, refers to changing requirements for the software, which are not met by respective changes of the software. Thus, the software may become unusable from the user's point of view. The second type of cause, the internal cause, is connected to the internal structure of the software: inherently to the maintenance process, it becomes more and more difficult to apply changes to the software. At a certain point in the lifecycle, the software may become unmaintainable from the developer's point of view. This can also make the software unusable, as required changes do not become effective. As the impact of software increases in daily life, measures to slow down or limit the impact of software aging become increasingly important. Parnas focuses on the developer's point of view and thus on the internal causes in the description of possible measures and answers the question of how to sustain the maintainability of software.

Digital games are a specialized kind of software. Therefore, they are also subject to the phenomenon of software aging. However, in the case of digital games – and especially digital serious games – external causes of software aging can be considered as having a greater impact. Externals causes of software aging can be seen mainly as changing requirements that are not met by the software. In the case of digital games, rising standards of computer graphics could be a reason for characterizing a game as old. As digital games rely on aesthetics as one mechanism to elicit enjoyment in the player, the requirement for impressive computer graphics is higher for computer games than for general application software. Furthermore, in the context of a serious game, changes in the domain knowledge to be conveyed by the serious game can make the game obsolete. This requirement hardly exists for digital games serving solely entertainment purposes. Both examples demonstrate that software aging may have further aspects in the context of serious games. A previous work [1] identified more systematically three categories of external software aging (technology, domain knowledge and user experience). As these categories are especially important for games, they are subsumed under the term *game aging*. In the following sections, these categories are described and illustrated using the study of MOBILITY.

3.1 Category: Technology

Description. *Technical game aging* occurs because of the changing environment of **hard- and software**. For example, from time to time new types of game consoles are released that outdate previous console types, e.g., in terms of performance. With regard to PC games, such as MOBILITY, the release of the operating system is a crucial requirement. For example, SimCity IV requires Microsoft Windows XP, which is neither sold nor supported by the producer. Virtual machines solve the problem of **operating systems** that are no longer available [1]. The field of videogame preservation provides further strategies to keep digital games available as cultural artifacts [2, 3]. However, in the context of serious games, it is important that the employed preservation strategy is not only feasible in terms of technology, but that the necessary effort is affordable. Legal issues are another potential source of aging, e.g., expiration of temporal licenses.

Study. The study, especially the guided interviews, revealed no severe technical challenges. This result was to be expected, as each semester students had been able to deliver solutions for the MOBILITY study task. Due to the ongoing maintenance by the supplier of MOBILITY, the game software runs on current Microsoft Windows systems. The only pitfall, mentioned by an interviewee, is the correct configuration of the compatibility settings. License issues have not occurred, as there is a specific agreement of permanent and unlimited educational use of MOBILITY.

3.2 Category: Domain Knowledge

Description. Many serious games, especially educational serious games, have to convey domain knowledge, e.g. about water infrastructure [13] or infrastructure management [1]. In general, each game is based on a model. This model, however, may be subject to changes over time. For example, a game encouraging physical exercises relies on a model of the effects of physical exercises on the human body [14]. If the underlying knowledge of effects of physical exercises changed due to further insights, the game would become outdated. The divergence between reality and the implemented model of the reality that happens over time is a common issue of serious games.

Study. *Expert Interview.* MOBILITY was designed twenty years ago. Although its domain of traffic system planning can be regarded as comparatively stable, the expert interview revealed changes in domain knowledge that are not yet implemented in MOBILITY. The most important of these is the current increase in e-mobility. MOBILITY does not contain any form of e-mobility, which is a major weakness when teaching the knowledge of modern means of transport. In addition to the complete lack of e-mobility means of transport, changes in the distribution of means of transport can also be observed. For example, car sharing was not as popular twenty years ago as it is nowadays. Unfortunately, MOBILITY cannot be adapted to this change of priorities.

Guided Interviews. The participants of the guided interviews acknowledged that MOBILITY is consistent with reality to a high degree. Only one participant named designated bikeways as a missing element in the game. Thus, most players do not perceive MOBILITY as outdated regarding domain knowledge.

3.3 Category: User Experience

Description. Games should elicit gaming enjoyment. However, when the use of games is mandatory playing becomes work to some extent [15] and the intrinsic motivation arising from gaming enjoyment is reduced. Similarly, outdated user interfaces, such as game graphics, may further reduce gaming enjoyment. Aesthetics is an essential part of gaming experiences. Thus, in general, user experience is considered to be subject to the aging process.

Study. *General Motivation.* Gaming experiences might have been influenced by a low motivation caused by the mandatory character of the game playing as part of the study task. To determine the general motivation of students regarding the study task indicators of motivation were measured using the expectancy value model of Wigfield and Eccles [9]. The model measures motivation by means of the categories of interest, usefulness and importance. Results (see Fig. 1) show that the interest in MOBILITY is higher than perceived usefulness and importance. Two items of comparative data [16, 17] show an inverse relationship. Overall, the values of all of the three categories can be rated as good, but they are consistently below the values of the comparative data.

Gaming Enjoyment. A key differentiator that distinguishes serious games from other interactive media is gaming enjoyment. Thus, gaming enjoyment has been measured using the EGameFlow questionnaire by Fu et al. [10] in a German translation provided by Eckardt et al. [18]. The results show very typical game characteristics (see Fig. 2) such as high immersion and high challenge. Although MOBILITY is a single-player game, it reached higher values in the category of social interaction than the comparative data [17, 18].

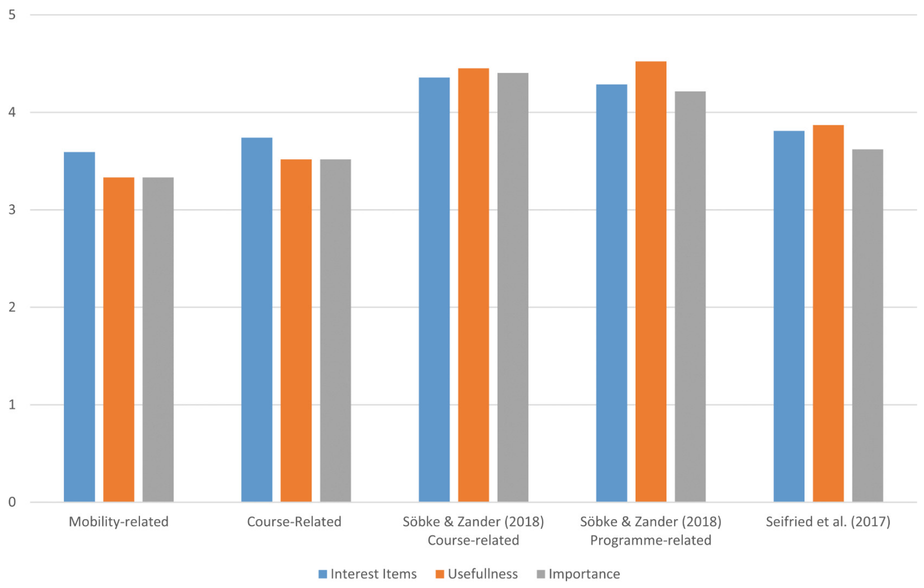

Fig. 1. Expectancy-value-model ([9, 19], compared to results in [16, 17] (5-point Likert scale))

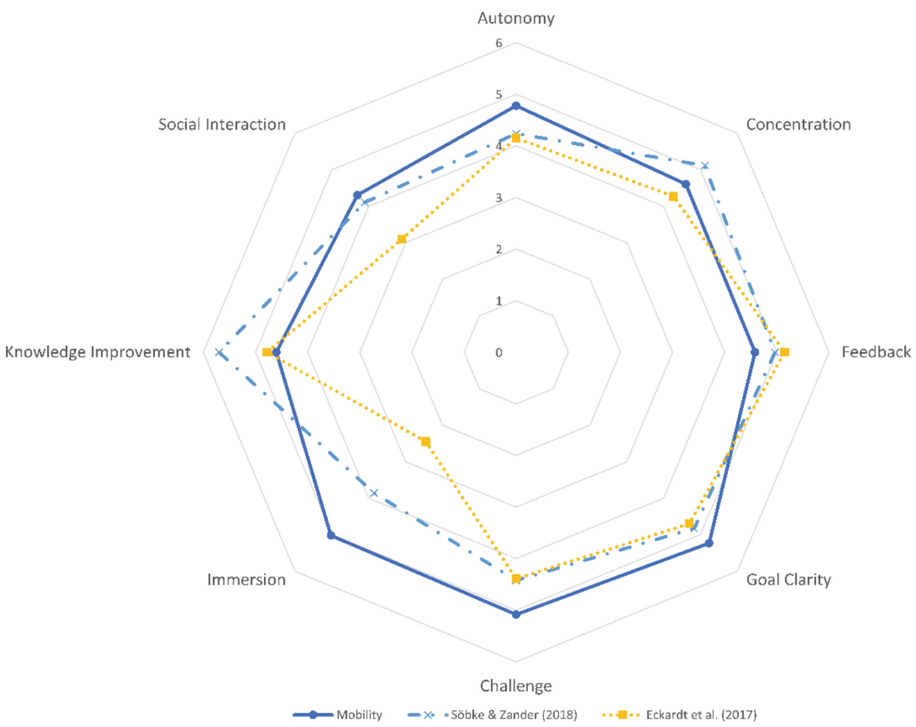

Fig. 2. Results of EGameFlow, compared to results in [17, 18] (7-point Likert scale)

Guided Interviews. The interviewed students assessed MOBILITY rather matter-of-factly. Most praised the short average working time of only two hours, but did not attribute much importance to the **gaming enjoyment**. Gaming enjoyment was severely limited by the mandatory character of the game playing. However, interviewees pointed out that they preferred the MOBILITY study task to other non-lecture tasks, such as those provided in the course on Structural Mechanics. Some interviewees criticized the simple game mechanics: compared to contemporary games, such as Cities: Skylines [20], the game lacks appealing comments on player actions. Randomly interspersed game events that make the game interesting and unpredictable and that tease the player in phases of inactivity are missing as well. At this point, the **game mechanics**, which contribute to the user experience, were identified as being aged. The user interface was explicitly named as outdated due to its low-resolution graphics and its partly aged interaction patterns, such as arrow navigation in a map. However, two interviewees acknowledged the particular charm of the user interface and all but one interviewee rated the user interface as easy and intuitive to use.

4 Discussion

MOBILITY can be regarded as a comparatively successful serious game. Based on a sufficient development budget, an attractive game has been provided, that has also reached a long lifetime. MOBILITY has benefited from an accompanying maintenance process that could be financed via shareware fees, which are still generating revenues. The native development in C++ was another advantage for the maintenance process. As a result, the game did not depend on the lifecycle of game engines, which can be discontinued or also be subject to aspects of software aging. Similar technical dependencies would arise through the use of effort-reducing authoring environments, such as StoryTec [21] or frameworks in general [22]. On the other hand, the game retains its “retro charm” through graphics and interaction patterns, which can be regarded as both motivating and demotivating. The monolithic simulation model of MOBILITY has proved to be disadvantageous. The simulation model makes it very difficult to integrate newer developments, such as e-mobility, into the game [23]. MOBILITY is an example for a serious game, which is still characterized by greater technical detailedness than contemporary commercial urban planning games with strengths in traffic system planning, such as in particular Cities: Skylines [20]. Another reason for still using MOBILITY is certainly the effort required to create a didactic scenario using a commercial urban planning game.

The findings of this study may be of limited applicability, as many serious games are research-oriented prototypes without the intention of a long lifetime. There may be further reasons not to aim at long lifetimes of serious games, such as volatile technical areas covered by serious games. A major problem of serious game development is its unsustainable financing. Often, serious games are developed in time-restricted projects funded by public donors. Frequently, the maintenance phase is not financially backed, which leads to games being discontinued [24]. Up to now, funding for serious games has mostly been provided by public donors. However, if the investments can be spread over such a long lifetime, it is at least more likely that other sources would also be able to contribute to the financing of serious games. Admittedly, the study is not representative due to the small size of the sample and due to the limited period of time covered by measurements. More experiences on complete lifecycles of serious games including all stakeholders are required.

5 Summary and Conclusions

The development of serious games is a complex process that requires high investments. The benefit gained from the investment increases with a longer lifetime of a serious game. However, the lifetime of serious games has hardly been systematically researched to date. Therefore, in this paper the simulation game MOBILITY was presented as an example of a serious game that has existed for almost two decades. Using the example of MOBILITY, the concept of game aging has been introduced as a categorization of possible lifetime-limiting factors. The categories of technology, domain knowledge and user experience are used. Indications of aging of MOBILITY were found in all categories. The same study, however, revealed that MOBILITY is still being used successfully as a valuable learning tool. The evaluation of the didactical scenario also showed potential for improvement. The systematic analysis of causes of game aging could support the creation of an evaluation scheme for assessing the aging status of any serious game. In addition to the causes, systematic analyses of impacts and consequences of game aging is to be done. Such analyses would allow determining the remaining usability of a serious game and support lifecycle management of a serious game. Further, the systematic analyses can be used as a basis to systematically define constructive measures, such as policies and technical remedies, to extend the lifetime of serious games. Moreover, research regarding the validity and completeness of the proposed game aging categories is necessary.

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