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Abstract: A lot of working environments today are very complex, and tasks are interdependent. This requires well-trained and skilled personnel. One example of such complex, interdependent system is a container terminal. A container terminal represents an important node in the multimodal transportation of goods. It connects the global sea transportation of goods with the more regional hinterland transportation, including the storage of goods within the terminal. In such a node, many operations have to be planned in order to ensure a high performance of the whole system. Planners of these operations need a good understanding of the situation, described as Situational Awareness (SA). To develop situational awareness, training activities that fit in the work processes, and relate closely to reality, are needed. In our paper, we introduce the concept of microgames as an approach to foster situational awareness and situated learning of integrated planning tasks within container terminals. The microgame used in this study is known as Yard Crane Scheduler (YCS), which was developed by a novel design approach known as game-storm, grounded in the triadic game design philosophy. Our experimental set-up includes YCS game play, a survey to measure SA, a survey to collect demographics and a post-game evaluation survey. The sessions include briefing and debriefing lectures. Test sessions were conducted with 142 participants consisting of game design students, supply chain and transportation students from Netherlands, Germany and the United States. Based on these sessions, we were able to evaluate the role of situation awareness in integrated planning activities, and the playability and usefulness of the microgame. In conclusion, based on our quantitative analysis conducted on the data from the test sessions we can state that SA is very conducive to integrated planning tasks in container terminal operations. Our qualitative results reflect that the microgame allows for an enjoyable game activity, while providing a meaningful situated learning experience.

Keywords: microgames, situational awareness, planning tasks, transportation

1. Introduction

A lot of working environments today show characteristics of complex socio-technical systems, consisting out of complex physical-technical systems and networks of interdependent actors (De Bruijn & Herder, 2009). For example, a container terminal can be defined as a complex socio-technical system, being an important node in the worldwide transportation network, connecting different modalities of transportation and storing goods (Saanen, 2004). Related to these characteristics, the planning of operations in a container terminal is complex, dynamic and interdependent. Operations that have to be planned are e.g. the location and time of an arriving vessel, the loading and unloading of the vessel, and the further storing or transportation of the goods from the vessel. Current planning practice involves a decomposition of single planning tasks, conducting them in a sequential manner. This approach leads to sub-optimal results, while the container industry is highly competitive, and time, money and quantity of goods handled play an important role (Zeng & Yang, 2009). Such dynamic, complex, and technology dependent work environment requires employees with adaptive skills (Penney, David, & Witt, 2011), characterized by the ability to handle dynamic situations, to deal with stressful events, to manage crisis situations, and to navigate unfamiliar or unpredictable work situations (Pulakos, Arad, & Donovan, 2000). Furthermore, it requires a holistic understanding of what is going on within the container terminal, called situational awareness (SA) (Endsley, 1995).

1.1 Situational awareness

The concept of SA includes the perception of a given situation, its comprehension, and the prediction of its future state (Endsley, 1995), and is seen as critical for successful collaboration (Stanton et al., 2006) and system performance.

The application domains of SA currently range from large-system operations to everyday affairs like driving. SA provides dynamic orientation to the situation, the opportunity to reflect not only on the past, present and future, but also on the potential features of the situation. The dynamic reflection contains 'logical-conceptual, imaginative, conscious and unconscious components which enables individuals to develop mental models of external events' (Bedny & Meister, 1999). However, the most widely used definition for individual situational awareness is 'the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future' (Endsley, 1995).

Some of the key benefits of SA for an individual are as follows - SA

- helps generate an up-to-date analysis of the complex and dynamic environment of the individual
- is critical for good decision making under time-pressure
- takes into account the impact of the actions on the surrounding environment
- enhances decision quality
- allows quicker response to abnormalities in the system.

Important features and mechanisms that individuals use to achieve SA include: attention and working memory, mental models, goals and goal-directed processing, preconceptions or expectations and automaticity (Endsley & Jones, 1997). However, SA is not a passive process, as the skills required for achieving and maintaining SA need to be taught and enhanced using specialized training programs. The learning process should also provide feedback to the individual allowing them to understand their mistakes and better asses the situation, leading to the development of more effective strategies and better ways to integrate information (Endsley, 1995). In our research, we have used one such specialized learning approach known as microgames based on situated learning, which are explained in section 1.2.

1.2 Situated learning and microgames

In complex and dynamic systems, where uncertainties will ever remain (Berkes, 2007), it is crucial for actors to gather as much understanding about the system as possible as background for well grounded decisions and actions. Thus, in complex systems, knowledge sharing and learning have become critical competencies for individuals and organizations, leading to increased performance (De Vries & Lukosch, 2009). Nonetheless, the time span between the moment when relevant knowledge is required and when this knowledge becomes obsolete becomes shorter and shorter. Innovative, authentic ways of learning are required to facilitate learning at the workplace, and to update knowledge continuously (Thelen, Herr, Hees, & Jeschke, 2011). Research has shown that there is a huge gap between the knowledge that is needed at the workplace and the knowledge and skills derived from formal learning activities (Tynjalä, 2008). Cross (2007) states that while 80% of the knowledge that is needed in the workplace is obtained through informal learning processes, e.g. by sharing experiences at the coffee machine, using solutions derived from online forums, only 20% if the knowledge stems from formal learning activities, like formal educational courses. This is also stressed by the notion of 'situated learning', an approach that argues for a conceptualization of learning as a social activity within communities of practice (Lave & Wenger, 1991). Informal learning is learning that is predominantly unstructured, experiential, and noninstitutional (Marsick & Volpe, 1999). Organizations nowadays have to encourage learning on the job to enable people to make more informed decisions on what to learn and do (Marsick & Volpe, 1999). As an answer to this particular learning need, it is crucial to develop situated mechanisms that support learning closely to the workplace (De Vries & Lukosch, 2009).

In our work, we explore the use of short games to answer the need for situated learning experiences that are engaging and motivating for an active learner. Unfortunately, not much development and research has been done so far in the field of so-called microgaming. In game design, the term is often used for describing mini-games that are part of a bigger game world. They are often used as incentive or bonus, and then do not always contribute to the overall aim of the main game. In our work, we refer to microgames as a learning experience, representing a stand-alone game with its own aim and meaning.

In a study within a high-school environment (Brom, Preuss, & Klement, 2011) could show that the use of microgames was at least as effective as traditional learning methods. Furthermore, the game group within the experiment was able to retain reinforced and integrated knowledge better than the control group. The microgames here were used as a brief activity between a traditional lecture and a de-briefing phase. Related to our own approach, this experiment focused on high-school students, whereas we try to explore the use of microgames in the professional field and in higher education. Additionally, (Brom et al., 2011) define their microgames as “relatively simple computer games that do not require special skills to play”, which is not applicable to the microgames we propose for the study and understanding of complex systems and situations. (Van Rosmalen, Boyle, Van der Baaren, Kärki, & del Blanco Aguado, 2014) illustrated the design and first experiences with mini-games based on the 4 Components Instructional Design (4C/ID) Method (van Merriënboer /Kirschner, 2012). These mini-games were meant to support students in higher education in acquiring knowledge about research methods. The evaluation showed that it is difficult to find a well-balanced design of the mini-games regarding the information provided – due to their characteristic of being a mini-game, a single game play should not take too much time, on the other hand, enough information has to be transported to play the game and to reach any learning effect. In our development process, we use a game design methodology to find the right balance of information transfer. The terms micro- or mini-game are often used in relation to mobile games, where they refer to the provision of small applications, that can also be used for learning or other serious purposes (Belotti, Berta, De Gloria, Feretti, & Margarone, 2004; Alsmeyer, Good, Howland, McAllister, Romero, & Watten, 2008).

In summary, there is no work done so far on the use of shorter games to foster active, situated learning at the workplace. In this article, we illustrate crucial concepts the microgames are based on, and introduce first experiences we have made with game play sessions. In the following section, we illustrate our concept of microgames. Thereafter, test sessions with students in higher education of the transportation domain and the game design field are illustrated, leading to first results on the experiences with and the usefulness of the microgames. A summary and future steps are presented in the concluding section.

2. The microgaming approach

In order to train skills needed in a container terminal, understood as a dynamic, complex socio-technical system, a microgame called Yard Crane Scheduler (YCS) has been developed. The microgame consists of a simplified representation of the quay side and yard side of a container terminal with the main goal for the player to conduct an interdependent planning of various terminal operations. The microgame approach is based on an instructional concept, called Microtraining (De Vries & Brall, 2008; De Vries & Lukosch, 2009; Overschie, Lukosch, & De Vries, 2010; Overschie, Lukosch, Mulder, & De Vries, 2013). Microtraining represents an approach of short learning activities with a time span of 15-20 minutes for each learning occasion, being based on instructional design considerations like social constructivism, connectivism, and learner typologies (see in more detail De Vries & Lukosch, 2009). Following the Microtraining approach, microgames support situated learning, as they always start from a well-defined problem, which is translated into a short simulation game. The definition of the problem and the translation into a microgame are part of a structured, iterative design process. This design process is based on the Triadic Game Design Philosophe (TGD) (Harteveld, 2011), and starts with a so-called game-storm session. In this session, the three components of a game design as proposed by (Harteveld, 2011) are defined together with the problem owner and the game designer (see figure 1). The three components are reality, meaning, and play, and according to TGD, they should be well balanced in order to develop an effective simulation game.

Figure 1: Facilitating a gamestorm session

The gamestorm sessions begin with defining the reality component of the game, namely making decisions on what aspects of the reference system, in our case, the container terminal, should be represented in a game. Also decisions are made on the fidelity, or the level of realism, the game should represent. This aspect refers e.g. to the audio-visual representation of the physical system that the game should illustrate. After that, the meaning component of the game is defined. This refers to e.g. the learning goals and the target group of the game. The meaning component describes for instance that the learning goal for the microgame introduced here is developing shared situational awareness in integrated planning tasks, targeting at planners working in container terminals. The third component, play, is the last one to be defined, and refers to all game mechanics that should be included in the game. It is for example important, and related to the meaning aspect, whether the game should include competition, and how challenging and difficult it may be for the user group envisioned. When all components are defined, game designers translate the results of the game storm session in a conceptual design of a game, which is again discussed with the target group. When an agreement on the conceptual model is reached, a first prototype of the game is developed, which is then evaluated by experts from the field, in our case, from container terminals (see for more details on the development process (Kurapati, Groen, Lukosch, & Verbraeck, 2014)).

Following the above described development process, the Yard Crane Scheduler (YCS) microgame has been developed. The game focuses on the integrated planning of loading and unloading sea vessels in the container terminal. The game offers two different screens, the operational mode, where an overview of the container terminal is provided, including the vessels to be arriving, the quay cranes, the yard cranes, and the scoring. This part of the screen allows allocating the cranes to the vessels and the containers in the terminal with easy drag and drop operations.

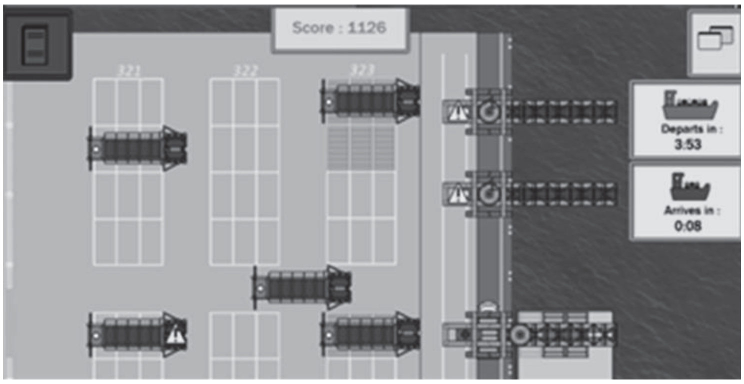

Figure 2: The operational mode of the YCS game

In this mode, game time runs, which has an immediate impact on the scoring of the player. In a negative way, when too many cranes are idle, the time of the idle equipment reduces the score of the player. In a positive way, when a vessel can leave the terminal early, the score of the player increases. In the other, the planning mode, the time freezes, so the player has enough time for planning operations. The main task here is to plan where the containers in the yard and on the vessels have to be placed in order to handle the vessel as quickly as possible.

Figure 3: An impression of YCS game play during a test session

The game's goal is to support the situational awareness (SA) of operational planners in container terminals. In the following, we will report on the outcomes of a case study conducted with game design students to evaluate the playability and the usefulness to develop SA of the YCS game.

3. Case study

3.1 Participants

Between October and December 2014, the YCS Microgame has been played with 142 students in higher education in The Netherlands, Germany, and the United States in total. The population consisted out of students from the logistics field as well as game design students. 38 students formed the game design group. The first two tests with the game were conducted with this group in order to explore especially the playability of the game. Further tests are currently still being conducted with logistics students and with professionals from the field. The game design students were recruited from two classes, one from The Netherlands, from a technical university (N=20), and one from a university of media design in Germany (N=18). The rest of the students (N=104) belonged to the logistics and supply chain domain in Netherlands and the United States. Though the overall sample size is 142, we were able to use only 107 data points, due to incomplete surveys. All the concerned university ethics committees approved our test sessions. We followed their strict guidelines for our sessions, so we could not make answers in the surveys mandatory. In this paper we will discuss the results on the playability of the game and its usefulness to develop SA in general for all students, and will derive more qualitative insights from the game design students with respect to game mechanisms, effectiveness as a learning tool and further improvements.

3.2 Experimental set-up and materials

Within a structured experimental session, the students were asked about their prior experience with games, were given a brief introduction to planning operations in container terminals, and then played the game several times. The researchers took observer notes during game play. Before a de-briefing on the experiences and lessons learned closed the session, the participants were asked to fill in a questionnaire. This questionnaire consisted of 5-point Likert-scale questions, including a self-rating technique on SA known as the Situation Awareness Rating Technique (SART) (Taylor, 1990). The results derived from the post-test questionnaire were calculated using Microsoft© Excel. With this set-up, we were able to combine a quantitative data collecting with qualitative approaches, in order to gather deep insights in playability and usefulness of the game. The experiments were conducted in a classroom setting at the two universities, where laptops were provided to the students for gameplay. An ethical committee approved the experiments and the participation of the students beforehand.

3.3 Quantitative results

The SART measurement of SA consists of three aspects: 1. Understanding of the situation (U) 2. Demand of the situation (D), and 3. Supply of information (S). The overall SA is calculate using the formula

$$\text{Situation Awareness, SA} = U-(D-S)$$

We analyzed the correlations between the performance in integrated planning tasks represented by the YCS microgame score and the SA measure. We found a significant positive correlation between them (Pearson's $r = 0.321$, $p<0.01$, $N=107$). This indicates that students that achieved better performance in the YCS game had higher Situation Awareness. Further, we would also like to report the group averages of individual components of the SA score. The results from the SA related questions imply that the game is able to support the understanding of the situation (m=4.7), while demand of the situation (m=4.7), and supply of information in the game are also high (m=4.4).

In addition to the SART survey, student perception on the usefulness of the game as a learning instrument for integrated planning tasks was measured in the form of a post game survey, by providing the average ratings on a scale of 1 to 5. Results show that the majority of the students state that the YCS game is able to reflect on the need for coordination of various processes in container terminal operations (m=4.1), which is an important requirement for integrated planning operations. The game was also positively valued as providing better insights in the importance of integrated planning (m=3.9). The question whether the environment was familiar to the students, resulted in a low score (m=2.6). This is due to the fact that all the participants were students with limited working knowledge of the professional working environment of container terminals. Despite the unfamiliarity of the environment, the participants were still very well able to gather information from the environment (m=4.7). The players assessed the game as valuable training tool to enhance performance in integrated planning tasks (m=4.0), while the value of adoption of the game by container terminals to strategize integrated planning approaches was given a slightly weaker score (m=3.6), but was still positively evaluated.

3.4 Qualitative results from the observations during game-play

Comments on the game, and suggestions for improvement were observed and written down by the researchers accompanying the test sessions. Students were highly engaged during the YCS gameplay. The facilitator walked around to answer any questions regarding the gameplay by the students. In the first session students had problems logging in the online game portal due to long urls. This issue was immediately rectified by providing short urls for the subsequent sessions. Very rarely, game froze due to technical errors and internet connection lapse, but students were instructed to restart the game when this happened. Students took 2 to 3 gameplay sessions after playing the tutorials to get fully familiarized with the game mechanics. Students enjoyed the music of the YCS game, while only one student reported that it was counter-productive for their performance. Students repeatedly questioned one aspect of the scoring mechanism, where idle resources lose points, for every second they are idle. The motive behind introducing the negative points for idle resources is supported by the industry experts from the container terminal domain. However students found it counter-intuitive and unfair. This concern was raised in all the sessions in both continents. Therefore we are considering modifying this scoring mechanism in the future version of the game. Most of the students wanted to continue playing the YCS game, as we observed from our online portal that several students were actively engaged in the gameplay for several days and some even several weeks after the test session.

3.5 Qualitative results from the observations during the de-briefing

The de-briefing of the game session consisted of a gathering the perceptions of students on the usefulness of the game, playability, player strategies, and possible improvements. This was followed by a lecture by the facilitator linking the objective of the game to practical applications and real world problems.

Many students found that the game very helpful to learn about integrated planning tasks in container terminals. A few students found the game too complex to learn and the actions non-intuitive. Players pointed out the importance of planning ahead. The majority of the players valued the game as well-designed and fun to play. Students suggested several improvements to the game, with respect to scoring mechanism as well as elements to be added to the game to further increase the element of ‘reality’ in the game. The suggestions will be considered for the future versions of the game.

3.6 Summary of results

In summary, the results briefly illustrated here indicate that the YCS microgame is able to address crucial skills needed in complex interdependent planning tasks. A crucial link between the YCS game score and Situational Awareness measure was found which backs the potential of microgames as training instruments for enhancing SA. The level of engagement of students expressed by the students during the game play as well as the debriefing session indicated that the microgame is not only a learning tool, but a highly engaging fun activity, which could further promote interest in learning beyond the game session. Even for students who are not familiar with container terminal operations, the game was able to provide enough information to develop a situational awareness for the need of integrated planning approaches. The comments of the students during game play underpinned that the understood the importance of integrated planning. Nonetheless, also weaknesses of the game were mentioned, and improvements were suggested, which will be implemented in the future version of the game.

4. Discussion and conclusions

Research shows the importance of situational awareness for the performance of complex systems, like container terminals. Specialized training approaches are needed to acquire, maintain and enhance SA in such systems. Designing realistic training processes that are situated in the workplace for such complex and dynamic is very crucial but very challenging. In our work, we try to reduce this research gap by exploring a novel approach known as microgame to enhance SA. We conducted 10 test sessions in Netherlands, Germany and the United States with 142 students to measure the effect of the microgame on SA and also to test its playability and usefulness. Given the significant correlation (Pearson's $r = 0.321$, $p<0.01$, $N=107$) between the microgame score as well as the observations from the gameplay and the reactions from the de-briefing session, we can conclude that microgames have a good potential to be training tools for situated learning to enhance Situational Awareness in complex systems such as container terminals. Students also opined both in surveys and during the debriefing that the microgame was a very useful to understand complex integrated planning tasks in container terminal domain in a short span of time. They also found it to be very fun and engaging. The de-briefing provides an opportunity to reflect on their decisions in the game and think about ways to improve them, which is crucial to acquire and maintain SA. This also strengthens our claim that microgame can be used for situated learning in complex environments to enhance SA. Nonetheless, remarks were made about the complexity of the actions within the game as well as minor deficiencies in the scoring mechanism. In the future, we will explore how the YCS game should be improved in order to increase playability, while still being able to represent the integrity of the planning tasks. The improved version will also be tested with user groups from the transportation and logistics domain, with experience and knowledge about operations in container terminals. We will especially investigate how realistic microgames should be in order to provide a meaningful, but still enjoyable learning experience. This will lead to recommendations for design choices to be made when developing micro- or minigames, used for the support of situated learning and situational awareness in complex systems.

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