Transferring an Educational Board Game to a Multi-user Mobile Learning Game to Increase Shared Situational Awareness

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Abstract. This paper analyses how multi-user mobile games can be beneficial to educational scenarios. It does so in several steps: Firstly, we introduce the field of logistics as a problem domain for an educational challenge. Secondly, we describe the design of an educational board game for the field of disruption handling in logistics processes, which aims to foster shared situational awareness (SSA). Thirdly, we introduce an open-source mobile serious games platform (ARLearn) and fourthly describe how the board game can be realized in this platform. The reader gets to know the problem situation of multi-stakeholder decision situations, learns about the design of a board game, and gets to know the open-source mobile serious game platform ARLearn.

Keywords: Mobile learning · Game-based learning · Multi-user games · Logistics · Multi-role game-design

1 Introduction

Decision-making in sociotechnical systems is complex and error-prone due to interdependencies of tasks, conflicting goals in distributed responsibilities and a lack of information among the various stakeholders involved in decision-making [1]. The proactive sharing of relevant situational information might help to improve shared situational awareness (SSA) among the stakeholders involved [2], which can lead to improved decision making processes within sociotechnical systems. Therefore, it is crucial to understand the role of communication among stakeholders [3].

The SALOMO[1] project aims to provide a training solution to create shared situational awareness (SSA) [2] to cope with this situation and to highlight the importance of communication. As multi-stakeholder decision situations confronted with time restrictions and incomplete information such as emergencies have been recognised as a

[1] SALOMO: Situational Awareness for LOgistic Multimodal Operations.

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relevant field for training [4–6], a multi-user board game has been designed, which emulates the decision process in the port environment in order to sensitize stakeholders in a value chain about communication and inter-dependencies.

To improve the scalability of the board game, we aim to provide a computerized version of the board game, simplifying the game distribution and execution by providing an automated execution environment for locally distributed players.

While most game-based learning approaches focus on skill development and motivational aspects, little work is reported that focus on multi-user learning situations and decision training. With this work, we also aim to provide new insights to this field of research, illustrated by an example in the logistics domain. The main contribution of this paper is to compare the board game and its mobile derivant from a design, deployment and execution point of view. While we do not report on a comparative study performed to assess the performance of each version, we rather give insights into design and application experiences as well as limitations of each approach.

The remainder of this paper is organised as follows: we start giving background information about the problem situation in logistics followed by an introduction of SSA as theoretical concept in multi-stakeholder decision situations. Based on this, we introduce and discuss our board game design as training game to increase SSA in a logistics decision situation. We continue with an introduction of the mobile serious game platform used and describe the transfer process of the board game to this platform. Finally, we draw conclusions.

2 Problem Situation in Logistics

In a huge international port, like the Port of Rotterdam, thousands of containers are moved every day in and out through several different channels in container terminals. A container terminal is the point of interaction between the different parties involved in container transportation. Containers need to be moved as fast as possible to meet the delivery time expectations of customers. Safety of the port and its operating personnel needs to be guaranteed at all times. To ensure the smooth operation of the port, different stakeholders, equipped with different responsibilities have to interoperate:

- *Control tower* ensures the overall smooth operation,
- *Resource planner* assigns the port personnel,
- *Yard planner* is responsible for the internal storage of containers in the port,
- *Vessel planner* is responsible to deliver containers to and from vessels,
- *Sales manager* is interested in customer satisfaction.

Unplanned and unanticipated events that affect the normal flow of goods and operations in supply and transport networks are termed as disruptions [7]. Unfortunately, disruptions have become common phenomena in port operations. The main categories are port accidents, port equipment failures, dangerous goods mishandling, port congestion, inadequacy of labour skills, hinterland inaccessibility, breach of security, and labour strikes [8]. Disruptions may cause severe ripple effects resulting in high costs, and have dire consequences on the social and economical wellbeing of the surrounding environment [9]. For e.g., a machinery breakdown in the port may lead to a security risk, which may cause an area to be closed. This may cause delays in the unloading of ships, which delays also their loading and planned departure, which affects the trucks, creating traffic jams etc. The operating individuals, mentioned above, need to take decisions to mitigate the disruptions together with external stakeholders. However, they are not always aware of these interdependencies and effects. Given the undesirable ripple effects of the disruptions in seaport operations, it can be deduced that the resilience of seaports, and their terminals, is essential for the resilience and robustness of transport networks as a whole.

As a first step to address this problem, this paper introduces a tabletop simulation game as an approach towards increasing SSA of planners and decision makers in seaport operations during disruption management to improve the resilience of seaport container terminals. In the following, we introduce how we conceptualize shared situational understanding and why it is so crucial in container transportation, before we illustrate how we translated this concept into a simulation board game.

3 Shared Situational Awareness

Situational awareness (SA) is the broadly accepted definition describing the level of awareness that an individual has of a situation, an operator's dynamic understanding of 'what is going on', including the perception and comprehension of a situation and the prediction of its future state [10]. Much has been written about the construct, yet it remains profoundly contentious. Of the definitions and approaches available, Endsley's three level, information-processing-based model has received the most attention [10]. Due to the significant presence of teams in contemporary organizational systems, the construct of team SA is currently receiving increased attention from the human factors community [11]. Distributed teams comprise members interacting over time and space via technology-mediated communication [11]. Team performance itself comprises two components of behaviour, teamwork (team members working together) and task work (team members working individually). SSA is multi-dimensional, comprising individual team member SA, shared SA between team members and also the combined SA of the whole team, the so-called 'common picture'. Add to this the various team processes involved (e.g. communication, coordination, collaboration, etc.) and the complexity of the construct quickly becomes apparent. Most attempts to understand team SA have centred on a 'shared understanding' of the same situation. Nofi, for example, defines team SA as: 'a shared awareness of a particular situation' [12] and Perla et al. suggest that 'when used in the sense of "shared awareness of a situation", shared SA implies that we all understand a given situation in the same way' [13]. In the following, we introduce a study in which we research in how far a simulation game session can support a group of players in developing SSA by providing different levels of communication and cooperation. The increased level of SSA should lead to improved resilience in container terminal operations.

4 Board Game Design and Experience

Simulation games can be defined as 'conscious endeavour to reproduce the central characteristics of a system in order to understand, experiment with and/or predict the behaviour of that system' [14]. It is a method in which human participants enact a specific role in a simulated environment [15]. In our case, we focus on the use of simulation games as a training tool, which is meant to improve communication between stakeholders, and to improve their SSA in seaport container terminals as an example of a complex system. For the conceptualization of our game, we follow a framework by Meijer [16], which is based on the work of Klabbers [17]. According to this, a simulation game is always designed with an objective (for learning purposes) or based on a research question (research purposes). The game consists of objectives, rules, roles, constraints, load and situation, which are controlled by the game designer as shown in Fig. 1 [16]. The framework presented in this figure forms the basis of the simulation game session presented in this research work.

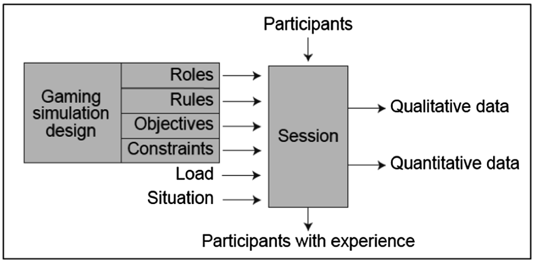

Fig. 1. Input and output elements of a simulation game session [16]

The disruption management game for intermodal transport operations in ports is a 5-player tabletop board game. Resilience is the ability for a system or organization to bounce back to normality even when affected by a disruption [18]. For seaport container terminals, bouncing back to normal can be quantified in terms of the Key Performance Indicators (KPIs). The KPIs can be categorized as efficiency of operations and costs, safety, customer relationship, sustainability, strategic/competitive position in the market, profits and losses [19]. As the game only focuses on operations, the KPIs considered for the game are safety, efficiency of operations, and customer satisfaction. Based on literature and brainstorming sessions with professionals in the container terminal business, the challenges in disruption management in container terminal operations have been translated into contextualized game play, based on the framework described in Fig. 1. The development of the game took over 8 months, as it was an iterative process following design, evaluation and validation cycles.

The game is presented to the participants in the form of a game session (see Fig. 2). One game master facilitates the game play. Every game session begins with a briefing lecture, introducing the concept and motivation, rules, set-up and scoring of the game (see Table 1).

Fig. 2. The board game in action

Table 1. Input and Output elements in the disruption management game

Input/output	Description in the game
Roles	Vessel planner, Yard planner, resource planner, control tower manager, sales
Rules	• There are individual game boards for each participant as well as an overall game board for the container terminal system with KPIs, contain varying information and rules based on the level of the game play • The KPIs are all maximum at the start of the game, they deteriorate after every round, and can be increased by mitigation actions of participants • Participants have information cards as well as action cards, the former used for communication, the latter for performing mitigation actions • Communication can be (virtually) done via e-mail, phone and conference, with differing effectiveness and costs. Limited tokens have to be used to communicate, showing communication costs (time and resources) • The information cards contain disruption details. After a round of information sharing, participants have to perform mitigation actions. • Mitigation cards vary for each round. They contain 3 choices from which participants need to choose one mitigation action card • Based on the actions of the participants the game master changes the scores of the KPIs after every round
Objectives	*Overall:* To maintain resilient transport operations *Individual:* To maintain individual performance indicators as well as the overall KPI of the terminal
Constraints	Information availability, time, resources to communicate
Load	Different disruption situations, different levels of escalation of disruptions, varying channels and cost of communication and information sharing
Situation	University classrooms; Logistics, supply chain and transportation companies; Professional and knowledge institutes
Participants	Academic researchers, students and professionals in the transportation, logistics and supply chain industry
Qualitative data	Observations from the game session by the game master, report of decisions after every round
Quantitative data	Post-game survey

The game play begins after the briefing session. Each level of the game play has five rounds. After every round, the individual and group scores are explained, when the game facilitator reads out the effects of the decisions made by the players on the KPIs. At the end of each level, an overview of the situation based on the participants' decisions is presented. For evaluation purposes, the game play is observed thoroughly by the game facilitator, while the decisions and scores are recorded.

The game session concludes with a de-briefing session, where the game facilitator explains the principles of disruption management, the challenges faced by practitioners, the relationship of the game elements to the challenges, a review of the scores and the reasons for obtaining such scores, alternative strategies, comparison between scores of different play groups and the reasons for it etc. This session is mainly to provide a learning experience for the participants.

After the de-briefing session the game master encourages the participants to provide feedback about the game and their experience, which is recorded. After the game session, the participants fill in an online survey on usefulness on the game.

The data gathered from the game and the survey is then analysed qualitatively to gather insights into disruption management for resilient intermodal port operations. Several game sessions were conducted based on the above design, played with 10 researchers, 15 experts, and 80 graduate students in in supply chain, logistics and transportation. The most important result that emerged from the analyses was the clear difference in the behavioural patterns of players at different game levels. Based on their awareness of the disruption scenario, roles and objectives of others, there was a difference regarding relevant information sharing for mitigating the disruption.

In level 1 of the game play, all the players had limited awareness of the disruption scenario, the effects of their decisions and their objective in the game. In level 2, players made good use of the available communication channels, as they understood where to send and receive information. Several discussions and negotiations were made among the players during level 3. Players teamed up to jointly mitigate the situation. Sometimes, players sacrificed their individual KPIs to boost the overall KPIs. Well-informed decisions were made in level 3.

The results from the mentioned sessions create a helpful learning experience in the field of disruption management and resilience of container terminal operations. While these positive results motivate us to continue, we also observed and collected a number of reasons motivating the transfer of the board game to a mobile version:

- As the board game requires a human game master to be present in order to control the complex game processes, the mobile version should be automated so players can play independent of a game master.
- This automatisation should also simplify the distribution and scalability of the game.
- Game results should be traceable for the necessary debriefing phase. While in the board game only the human memory is available for debriefing, the mobile version should track all user interactions and decisions.
- The board game requires all players to be present in a single room. While this fosters a common game experience, it imposes an unrealistic situation, as in reality the different persons would be distributed across the port.

In the following, we illustrate how the board-game concept has been translated into a mobile multi-player version, taking into account above-mentioned reasoning.

5 ARLearn Platform for Mobile Serious Games

Based on the board game described above, we aimed to design a computerized version using ARLearn. ARLearn is a platform for the design of mobile process-based learning games [20] comprising an authoring interface which allows to bind a number of content items and task structures to locations, events, and roles and to use game-logic and dependencies to initiate further tasks and activities. The platform has been recently used for several similar pilot studies in the cultural heritage domain [21].

One key reason to use ARLearn for the multi-stakeholder decision training scenario described above is its flexibility in designing games for multiple users organised in different teams and using different roles. In a role-based game design, media artefacts can be bound to roles, meaning that they will be only be visible to players that have the same role assigned. The role-based game-design can be used to model situations with incomplete, personalised information and individualised game processes. Consequently, a multi-role game can be designed in a manner that only a collaborative effort of the players in various roles leads to game success. Thus, the event-based game model of ARLearn allows simulating mission critical real-life situations and conditions, placed in an augmented real life situation. ARLearn also records user activities and allows reviewing game runs for the debriefing stage. Commonly used smartphones (Android, iOS) can be used to play ARLearn games. The authoring interface allows copying and modifying games, allowing creating variations.

Based on its flexible, pattern-based game-design approach [22], ARLearn has already been applied to other learning scenarios, where a number of players need to interact and cooperate in order to reach a satisfying goal in a disruption or emergency situation. For the United Nations High Commissioner for Refugees (UNHCR), we created a role-playing game, which simulates kidnapping situations in order to train employees how to react in such situations [23]. In the EmUrgency project, we designed a game educating bystanders of cardiac arrest how to behave in such a situation [24].

Looking at other approaches for mobile serious games, we find a few related approaches. The ARIS platform [25] offers the possibility to author location-based mobile games. While ARIS has been successfully used in several application examples [26], it does not support multi-player/multi-role games. QuestInSitu is a mobile learning platform including authoring which mainly focuses on assessment [27] in location-based contexts. Robles et al. [28] describe an implementation of a team-enabled mobile gaming platform. The location-based task model allows for linear games, where a new task description follows the previous one.

6 Transfer of the Board Game into a Mobile Serious Game

In the mobile version of the board game, the game master is replaced with the automated ARLearn game logic. The game design follows the board game as described in the section 'Board game design and experience'. Figure 3 depicts one round in the game process. Each level consists of five rounds, which are synchronized after each decision. Each round gives access to a new situation description.

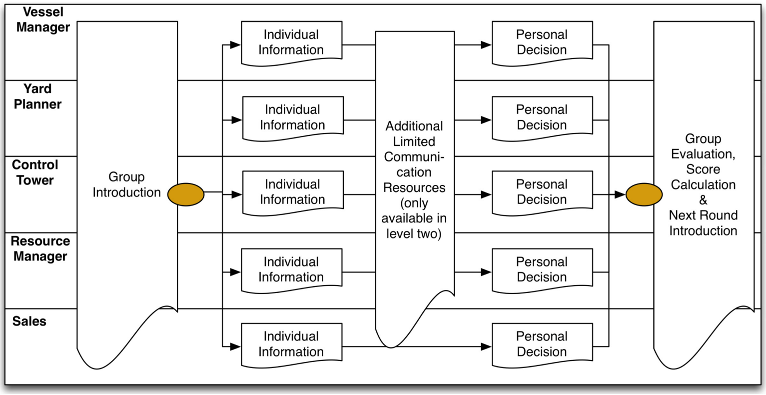

Fig. 3. One round of level one/level two with communication

While level one of the game isolates the different players completely, subsequent levels give access to limited communicative resources. This shall foster the players to exchange information creating awareness for other player's situation and the overall consequences of own decisions (Fig. 3). The ARLearn-based game differs slightly from the board game:

- The five players can potentially play the game in separate locations as their mobile devices are synchronised automatically via ARLearn. The ARLearn game engine automatically synchronizes the game state between the different players.
- No human game master is required, as the game engine automatically updates the game state, evaluates player decisions and distributes information. The game rules, processes, the decisions and all other game resources are encoded as game design script in ARLearn.

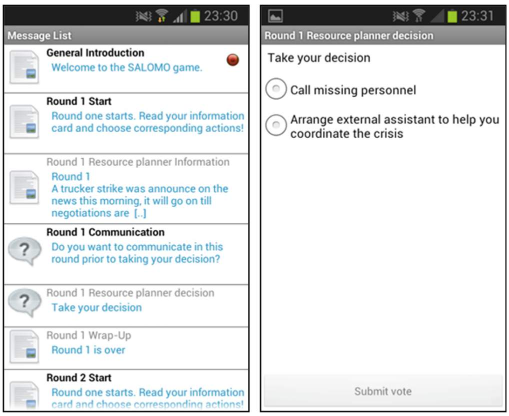

Fig. 4. Screenshots of the SALOMO game: message overview and decision point

Table 2. Comparison of board game and mobile game

Dimension	Board game	Mobile game
Execution of game processes	Human game master necessary; scores and game progress are calculated manually.	Game process automatized. No human game master required; scores and game progress are calculated automatically.
Scalability	Game scalability depends on the number of trained game masters available.	Game can be distributed via appstores. Scalability limited to the technical scalability of the game engine.
Location independence	All players need to be at a single location grouped around a table.	Players can be locally distributed. Each player plays with a mobile device. The game engine syncs the game state across devices.
Introduction support	Game master needs to explain the game background, game mechanics and processes as well as the available actions in each situation.	Introduction to the game background is part of the game. Actions are context-dependent: players can only choose from meaningful actions. Game handling needs to be explained (installation, mechanics), e.g. with a tutorial.
Debriefing support	Game master collects decisions and actions for debriefing. The game master is also present during the game phase and can monitor personal or non-verbal feedback.	Logging data for debriefing is automatically collected and can be reviewed. However, despite the data being available, the debriefing session should be guided by a trainer in order to interpret the data and to gather additional personal feedback.
Group experience	As participants play in one location, informal interaction between players takes place, increasing group experience.	Due to the possible local distribution, players can play the game isolated. Communication outside the in-game mechanisms more difficult than in the board game variant.
Realism	In the board game, players are explicitly set in a game setting that differs from their regular work setting. They play around a table – a setting that would normally only be used for meetings.	The mobile game simulates isolated players communicating via different messages (text, image, video, audio). While the game scenario restricts the communication between players, the isolation and the message style communication creates a more realisitc game play situation.
Reusability and variability	The board game supports a fixed number of disruption scenarios. Varying these scenarios requires new versions of the board game to be produced.	The authoring tool used to create the mobile game allows to create variations of the same game. The game design and game processes can be updated and developed continuously to extend the available scenarios or to reflect experiences from previous game trials.

- The mobile devices provide a realistic situation scenario, as the players use communication means similar to their daily activities as the game interaction is based on mobile devices: users receive messages and interact with question items. Multimedia dialogue sequences complement the message driven approach to provide more immersive situations.

Figure 4 displays screenshots of the SALOMO game showing communication messages and decision points.

The ARLearn platform used supports the automatic logging of all player interactions. Through a web-based front-end this data can be retrieved and used for a debriefing session. While the logging data is available, the debriefing itself is not (yet) automatized and has to be performed together with a trained expert.

7 Conclusion

From disruption management processes observed at a large international port, we have designed a board game simulating these processes with a varying degree of communication means available to players. This board game has been successfully trialled with various user groups. Some difficulties of this board game design are that it requires a skilled game master to be available during game play, which leads to decreased scalability of the game, and that it requires all players to be within a single room to play the game, which is unrealistic for the stakeholders in a big port.

Consequently, we have chosen a multi-user, multi-role enabled mobile game environment (ARLearn), to create a computerized version of the game, which can be played by players in the different roles simultaneously. The players play with different mobile devices and do not need to be at the same location.

While we did not perform a comparative study to evaluate the mobile game against the board game directly, the main contribution of this paper is to compare the applicability of the two different game scenarios in various training settings and to assess their value from a design point of view. Table 2 consequently compares the board game and the mobile game along the dimensions execution, scalability, location independence, introduction & debriefing support, group experience, realism, reusability and variability.

Rather than ranking one over the other, the presented table shall guide designers of multi-user decision training games in order to chose their way of implementation according to the training setting at hand. With these dimensions in mind it is possible to create immersive multi-user games simulating complex decision processes gaining SSA among stakeholders and raising awareness for the importance of pro-active communication as a key element of shared decision taking. Where group experience and debriefing support are top priorities, a board game can be seen as preferred option. In scenarios, where realism, location independence, scalability, or reusability are in focus, the mobile game appears to be the preferred solution.

8 Future Work

The work described here represents a starting point for the sound design and implementation of multi-user decision training games for various training scenarios. While we have first results indicating that this kind of games is helpful and can provide effects [29] in other case studies, we are looking for ways to further formalise the design and implementation of multi-user decision training games [30]. Our research therefore follows two directions: firstly, the further development of our game scenarios and technical implementation focuses on enhancing the immersiveness of our games. Secondly, the further evaluation of training scenarios in various settings should deliver stronger evidence about their usefulness and about measurable effects.

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