

## MULTI-STAKEHOLDER DECISION TRAINING GAMES WITH ARLEARN

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**Abstract:** *Serious gaming approaches so far focus mainly on skill development, motivational aspects or providing immersive learning situations. Little work has been reported to foster awareness and decision competencies in complex decision situations involving incomplete information and multiple stakeholders. We address this issue exploring the technical requirements and possibilities to design games for such situations in three case studies: a hostage taking situation, a multi-stakeholder logistics case, and a health-care related emergency case. To implement the games, we use a multi-user enabled mobile game development platform (ARLearn). We describe the underlying real world situations and educational challenges and analyse how these are reflected in the ARLearn games realized.*

**Keywords:** *Mobile learning, Game-based learning, Multi-user games, Decision processes, Multi-role game-design*

### 1. INTRODUCTION

Serious games received a high interest in recent years [1]. Research focus is often on motivational potential and low-threshold learning opportunities [2][3] as well as the ability to address various target groups [4][5]. Mobile learning games are suggested to provide potential for learning and teaching in terms of ‘assessment’, ‘learner performance’, ‘skill development’, or ‘social and emotional well-being’ [6]. Even though multi-user gaming environments are around, little research exploits multi-user enabled platforms for learning, apart from the use of virtual worlds for multi-user games [7][8].

Multi-stakeholder decision situations confronted with time restrictions and incomplete information such as emergencies have been recognised as a relevant field for specific training approaches involving table-top exercises [9] or (non-computerized) tactical decision training games [10]. First prototypes towards the use of collaborative computer games are also reported [11]. The systematic use of game platforms is still in its infancies. This paper explores a multi-user enabled mobile serious gaming platform for a number of real-world, multi-stakeholder decision training situations. The three cases we use are:

1. Decision and action processes in a cardiac arrest emergency involving bystanders
2. Decision processes in a hostage taking case involving stakeholders of a distributed organization
3. Distributed decision processes in a logistics value chain as reaction on process disturbances at a large European port.

In the following section we will introduce and motivate the three cases and the challenges involved. We subsequently reflect on related work and derive requirements for the described educational scenarios. Then, we introduce the technology used followed by the game-designs applied. Finally, we compare the three cases and discuss our findings.

### 2. BACKGROUND

#### Bystander decisions processes in emergency situations

Cardiac arrest is one of the main causes of death worldwide. In Europe alone it is estimated that about 350 000 people die from cardiac arrest each year [12]. Traditional interventions have not sufficiently decreased mortality rates and increased the rate of cardiopulmonary resuscitation (CPR) especially by first responders. This rate of first-responder CPR is critical to increase survival rates since the professional medical emergency services need approximately 8 – 10 minutes to arrive at an incident [13]. The project EMuRgency aims to increase the rate of bystander resuscitation and thus survival chances by socio-technical innovations. One of these innovations is the use of a training game. Traditional training approaches for pre-hospital resuscitation training combine lecture-centric phases with motor-skills training on a mannequin. From an educational perspective this training format delivers only short-term knowledge and competence building whose retention times is normally not longer than 3 to 6 months [14].

#### Hostage taking situation

The Office of the United Nations High Commissioner for Refugees (UNHCR) leads and co-ordinates international action to protect refugees and resolve refugee problems worldwide. As this organisation is confronted with kidnappings, employees are trained on how to deal with such situations. To better equip staff, the Global Learning Centre (GLC) of the UNHCR organizes security management trainings worldwide. Typically, workshops are organized over a 3-5 day period covering policy-based information, such as standard operating procedures, as well as immersive simulation exercises, such as hostage taking, bomb threat and other security-related scenarios.

A role-playing game is part of these workshops, where learners are split into groups representing the different

roles that are present in an actual security situation. The hostage-taking role-playing game is a highly immersive experience for the learners, in which they have to deal with stress, act quickly, collaborate and negotiate in order to 'save the hostage'. Running the game is an intensive exercise, for the participants and for the organizers and facilitators encouraging the whole team to engage in the chaotic development of a hostage situation. As the game is carried out at a rapid pace it can be difficult to have an all-inclusive debriefing in which all roles of all teams receive appropriate feedback. The debriefing and reflection phase of the activity is a major learning point. Debriefing allows learners to reflect on what they learned, the challenges and risks associated with hostage taking situations and their personal capabilities.

This aspect has led to the development a technology-based alternative for the original game, which addresses the following training issues [15]:

- Enabling the creation of different reusable variations of a game-design for emergency security response, covering initially the hostage-taking situation.
- Enabling 'on the fly' messaging to participants and real-time assessments of activities.
- Semi-automatic management of the game enabling more participants to experience the exercise.
- Creating a log through the game of responses and interactions, which can be used by the trainer to provide feedback during the debriefing session.

### Decisions in logistical value chain

In a huge international port, like the Port of Rotterdam, thousands of containers are moved every day in and out through several different channels. Different interests have to be met during these operations: each container needs to be handled properly according to specific rules (e.g. cooling for containers containing food). 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 storage of containers in the port's internal storage places,
- *Vessel planner* is responsible to deliver containers to and from vessels,
- *Sales manager* is interested in customer satisfaction.

Disturbances (such as delays, malfunctioning machinery, accidents, strikes) may cause severe ripple effects resulting in high costs: 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. The mentioned stakeholders plus the independently operating logistics operators (ships, vessels, trucks, trains) take decisions according to the

disturbances, which also affect other stakeholders. The operating individuals are not always aware of these interdependencies and effects.

The SALOMO project aims to provide a training solution to create shared situational awareness [16] to cope with this situation and to highlight the importance of communication. To sensitize stakeholders in a value chain about communication and inter-dependencies, a multi-user board game has been designed, which emulates the decision process in the port environment. Five players, each in one of the different roles play three levels of five rounds each, taking decisions based on incomplete information. New levels give access to (limited) new communication means to foster shared situational awareness. A game master controls rules and scores. The goal is to balance several scores: individual scores and a shared overall performance score. Decisions affect scores either positively or negatively.

In order to simplify the game process, we aim to provide a computerized version of the board game, simplifying the game distribution and execution by providing an automated execution environment and by allowing playing the game with locally distributed players.

### 3. RELATED WORK

Decision-making in sociotechnical systems (large technical systems involving many stakeholders) is complex and error-prone due to inter-dependencies and lack of information [17]. Additional situational information might help to gain shared situational awareness (i.e. "a common relevant picture distributed rapidly about a problem situation" [16]). Therefore it is crucial to understand the role of communication and inter-dependencies among stakeholders [18].

Several educational theories relate to the goal of embedding learning processes into real world application and performance. The anchored instruction approach [19] aims to decrease the problem of inert knowledge through the presentation of real authentic problems and the active exploration by learners. The theory of situated learning [20] is grounded on the assumption that learners do not learn via the plain acquisition of knowledge but they learn via the active participation in frameworks and social contexts with a specific social engagement structure. Learning games provide such environments, in which learning processes can be embedded in situations similar to real life. They provide realistic problem situations and allow players to actively explore solution paths. Multi-user games can also provide the social context, in which learning takes place. In her review of immersive games, [21] stresses the importance of linking the experiences made in a game with their application in real world practices. Game-based approaches towards the distribution of knowledge for emergency situations can also be found. However, many of them focus on the factual knowledge rather than the decision process [22]. In the approach presented here, we aim to combine factual knowledge provision with decision training.

The importance of specific training towards fast and process decisions in emergency situations has been addressed by approaches such as table-top exercises [9]. To improve decision training, specific training games have been proposed [10][23][24], in order to put trainees in realistic situations. However, these games are often not computerized and thus lack some of the opportunities computer games offer (such as autonomous playability, tracking of user decisions and actions, scalability). Also, these games often require a human game master to track the game progress [25]. Computerized decision training approaches involve immersive virtual reality scenarios [26], which put the player into a realistically modelled situation or agent-based approaches, which aim to model co-player behaviour [27]. While these developments deliver single user games, first prototypes have been successfully created towards decision training using collaborative games [11].

#### 4. REQUIREMENTS

All three cases introduced involve several persons in the decisions, decisions need to be taken quickly and decisions have to be taken in a situation of incomplete, misleading or wrong information. The different persons involved in the decisions act in different roles, which have or require different information. Success can only be gained when the different persons involved cooperate. To provide a training environment for these scenarios, we derived a number of specific requirements, which are summarized in this section.

- (R1) An environment supporting these scenarios needs to be multi-user enabled to support the different participants in the educational process. Multiple users need to be able to play games together using different devices. Users need to have personal views on the game state. Teams shall be supported.
- (R2) Different roles for different participants needs to be supported, individualising information visibility, tasks, communication, and process steps.
- (R3) Individual information supply and messages depending on player roles shall be possible. Together with (R2), this allows for personalized games according to player roles. Games can be organised such that only collaboration leads to success.
- (R4) The game process shall allow interweaving player decisions with game events and shall allow semi-automatic game execution. Players shall be confronted with the consequences of their decisions. The game processes designed with the platform need to define alternative paths and decision points.
- (R5) The game process should be supported on mobile devices. Events, notifications, decisions should use standard channels. This requirement supports the immersive character by staying close to the environment used to the players.
- (R6) Re-use of games including variations and simple modifications shall be possible. While not related to gaming, this supports evolutionary game designs.
- (R7) The environment should log game activities for later game reviews, debriefings, and the necessary

reflection: the game process can be analysed and decisions taken can be discussed.

We are aware, that these requirements not completely describe the necessary features of a game platform (such as user interface aspects, interactivity elements, game patterns, media support). However, here we focus on requirements relevant for multi-user games and decision training. Also, we omit here details of our user-centred requirements analysis processes for our cases. More detail on the technical requirements can be found in [28], [29], and [30]. Details on our user-centred approach and the involvement of stakeholders are published in [15], [16], and [31].

#### 5. TECHNOLOGY

We are designing the training games using the ARLearn-platform. ARLearn is a platform for the design of mobile process-based learning games [28]. The platform consists of an authoring interface that enables game-designers to bind a number of content items and task structures to locations, events, 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 [29]. The cloud-based, Google App Engine hosted ARLearn service is an open-source project that permits others to reuse and contribute.

Various kinds of clients connect to this game engine. The Android client allows for game play in the real world, while the StreetView-based client (called StreetLearn) offers the same game logic a virtual environment [30]. An ARLearn game is a reusable game logic description, comparable to CSCL scripts, which model collaborative learning processes [32][33]. However the ARLearn processes explicitly include game patterns [34] such as competition, collaboration, or scoring into the process design and thus embed the collaborative learning experience in the game context. A game run corresponding to a game defines users grouped in teams. While playing, users generate actions (e.g., “read message”, “answered question”) and responses. This output is also managed within the realm of a run.

All actions and items within an ARLearn game can be bound to a real world context (a location, a point in time, a previous action, or a tag to be scanned, which is connected to a real world object). This way, games can be placed into the real world and consequently augment the player’s environment with game play elements, information, and actions to be taken.

One key reason to use ARLearn for the multi-stakeholder decision training scenarios 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. For instance, a message “answer an incoming call from journalist“ can be bound to the role “communication officer“. Content that is not

bound to a role is visible to all players. Dependencies can be used in combination with roles. This is useful when content needs to appear or disappear when a role performs an action. This enables expressing actions like “make an information package available to all users, when the team leader enters the control room”. Furthermore, 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.

Looking at other approaches for mobile serious games, we find a few related approaches. The ARIS platform [35] offers the possibility to author location-based mobile games. While ARIS has been successfully used in several application examples [36], it does not support multi-player/multi-role games. QuestInSitu is a mobile learning platform including authoring which mainly focuses on assessment [37] by putting them into location-based contexts. [38] describes 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. In summary, the following reasons lead us to use ARLearn to design the games for the three cases.

- ARLearn is multi-user enabled and supports multiple roles and teams within one game (R1 & R2).
- Game processes can be individualised according to player roles, so that incomplete or individual information supply is possible (R3).
- The event-based game model of ARLearn allows to design realistic game processes, which simulate mission critical real-life situations and conditions, placed in an augmented real life situation (R4).
- Commonly used smartphones (Android, iOS) can be used to play ARLearn games, which simplifies game distribution (R5).
- The authoring interface allows copying and modifying games, allowing creating variations (R6).
- ARLearn records user activities and allows reviewing game runs at a later stage (R7).

Furthermore, the ARLearn platform is location-aware, which allows for realistic game-play settings and allows for mixtures of competitive and collaborative games. In the next section we discuss the multi-role-based game-designs, which we have implemented with ARLearn to realize the abovementioned scenarios.

## 6. GAME-DESIGN

In all three cases the games are organized in a three-phase setup, including an introduction phase, a game-phase and a debriefing phase.

- The *introduction phase* includes technical setup, explanation of game handling, rules, and aim. Teams are formed, roles assigned and the game starts.
- In the *game phase*, the teams play the game. The three cases follow different game processes as described in the following sections.

- In the *debriefing phase* game results, team behaviour, and expected outcomes are reviewed for individual behaviour and team performance. Further mechanisms can be included (tutor-based individual feedback, self-assessment, gold standard videos).

In the following we focus on the game phase of our cases.

### Heart Run game for bystanders in emergency situations

The main goal of the heart run game is the acquisition of skills and abilities related to the Chain of Survival, i.e. (a) to prevent cardiac arrest, (b) to buy time, (c) to restart the heart and (d) to restore quality of life. The game-design is oriented on the design recommendations for situated learning scenarios. The tasks involved in the game aim to produce authentic learning contexts. **Figure 1** shows the game-design. The game comprises three roles: A CPR role, a documenter role, and a role responsible to find and get an Automated External Defibrillator (AED) to the victim.

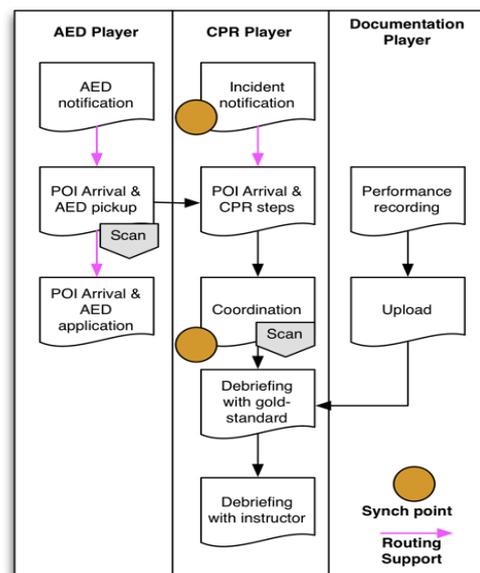


Figure 1. Game-design resuscitation game

The game is initiated with a notification informing the CPR player about a victim in the direct surrounding. The player starts to identify the location of the victim. The stress level of the player can optionally be increased with sounds or visuals that represent the decrease of oxygen in the victim’s body. At the victim, the CPR player has to perform the steps required in case of a witnessed cardiac arrest (securing the area, calling for help, controlling the breath and starting CPR). The documentation player records this process. The AED player receives the location of a nearby AED, has to find it and bring it to the victim’s location. Now the CPR player and the AED player have to coordinate their action in terms of continuing CPR and at the same time preparing the application of the AED. The documentation player records the performance. The game ends after 8-10 minutes, when the emergency services arrive. The players can change roles and play the game again.

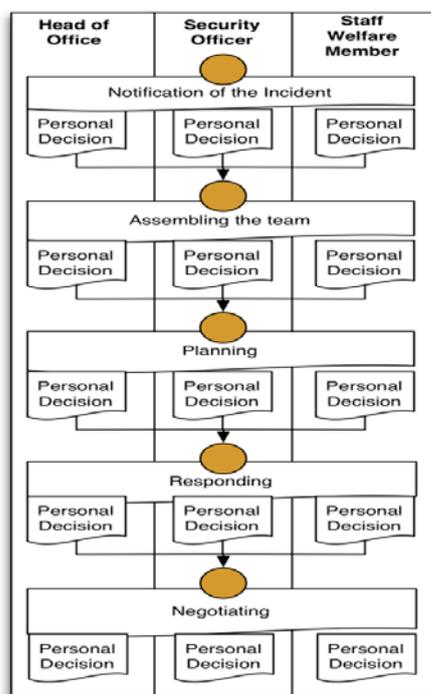
More detail on the heart run game-design can be found in [31]. **Figure 2** displays screenshots of the HeartRun game implemented in ARLearn. The information displayed on the screen depends on game state and player situation: only when the player is at the right location or takes the right decision, the corresponding instructions are shown.



**Figure 2.** Screenshots of the HeartRun game: welcome message, decision point, and instructions

situations but it can take time till this team arrives and offices need to know how to respond prior to their arrival. The players take one of the following three roles: head of office, security officer and staff welfare member. The hostage-taking simulation was designed such that players in all roles play the same game but have to react

### Hostage taking game



**Figure 3.** Game-design of the hostage taking game with five rounds of information and decision

The hostage taking game prepares the participants on the response procedures to be initiated immediately when a staff member is taken hostage. A Hostage Incident Management (HIM) team is deployed eventually in such

differently based on their roles. The game is organized in 5 rounds (see **Figure 2**).

*Round 1: Notification of the incident.* The game starts with a plea for help by Jerry Khan, a fictitious UNHCR employee that was taken hostage. This video message features a blindfolded actor and creates an authentic context. This message is broadcasted to all the roles. Players take decisions on what to do next, depending on their specific role. The head of office (role A) for instance can decide to “notify the Designated Officer (DO)” while a staff-welfare member (role C) should select the option to “contact senior management”. Depending on the decision taken, they receive feedback.

*Round 2: Assembling the team.* The head of office is informed by the DO that a hostage incident management team will be dispatched. The players need to contact the security advisor (role B) and staff welfare officer (role C) to assemble in headquarters for a planning session.

*Round 3: Planning.* When the team has assembled, an audio recording of the DO requesting the team to work out a reception plan is sent out. The team has to work out this plan on a flip-board and to capture a photo of the plan with their device. Next, the participants are asked to split up and go to their individual rooms.

*Round 4: Responding.* Role A and role C are to respond to calls from a journalist and a distressed family member respectively. Role B in the meantime receives a task from the DO to prepare a Proof of Life (POL) question.

*Round 5: Negotiating.* All roles gather together again, triggered by a message from the hostage takers. A negotiation with the hostage takers is simulated. The game ends when the Hostage Incident Management (HIM) team has arrived and is ready to take over.

Figure 4 shows screenshots of the hostage taking game with an overview of messages and a detail view of a task description and an audio.

### Decision game for logistical value chains

Based on the logistics board game described above, we designed a computerized version using ARLearn. The game master is replaced with the automated ARLearn game logic. The game design follows the board game: it is playable with five players in pre-defined roles. Per round, players are confronted with the description of a disturbance situation, which affects the functionality of the port, e.g. a trucker strike. Each player receives a different situation description, depending on the role assigned (while e.g. the resource planner knows about the strike, the yard planner only receives information about missing personnel). The players need to take decisions according to the incomplete information. Each decision may affect the decisions of other players, which is modelled in terms of score impact. When all players decided in the current round, the game progresses to the next round. Figure 5 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.

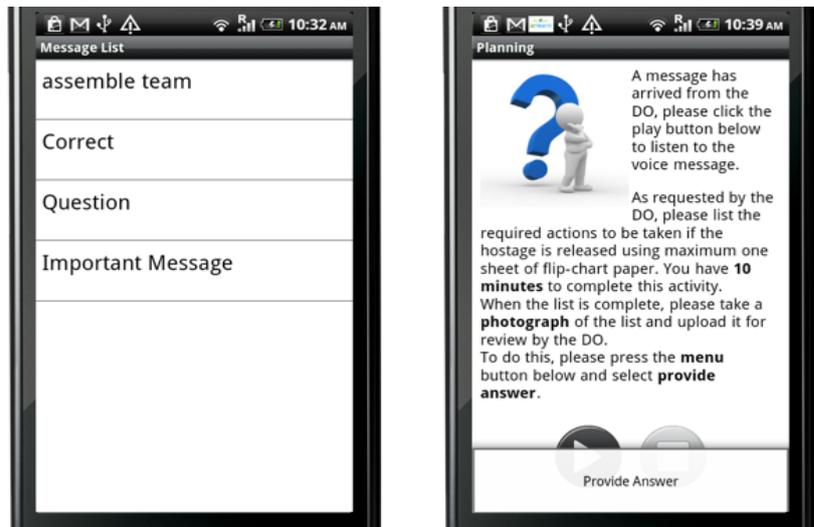


Figure 4. Screenshots of the hostage game: message overview and task description

The ARLearn game differs slightly from the board game:

- Players can potentially play the game in separate locations as their mobile devices are synchronised automatically via ARLearn.
- No human game master is required, as the game engine automatically updates the game state.
- The mobile devices provide a realistic situation scenario, as the players use communication means similar to their daily activities.

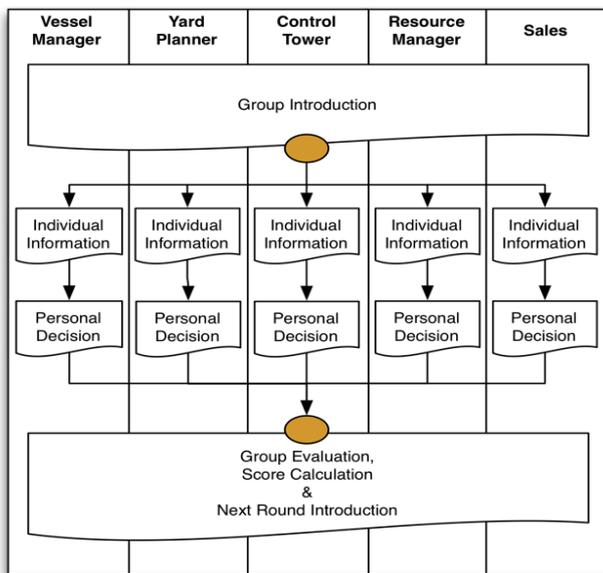


Figure 5. One round of the logistics game-design level one with isolated players

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 in order to create awareness for other player's situation and the overall consequences of own decisions (Figure 6).

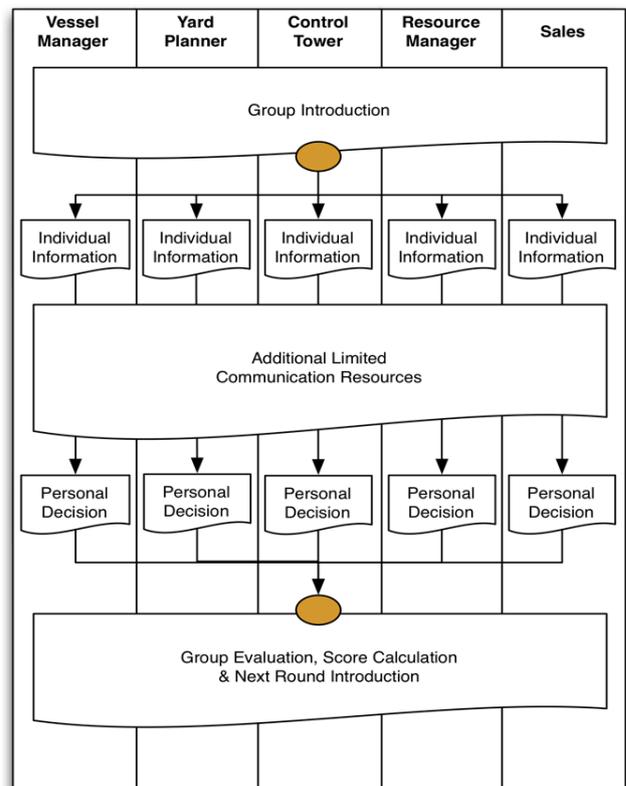
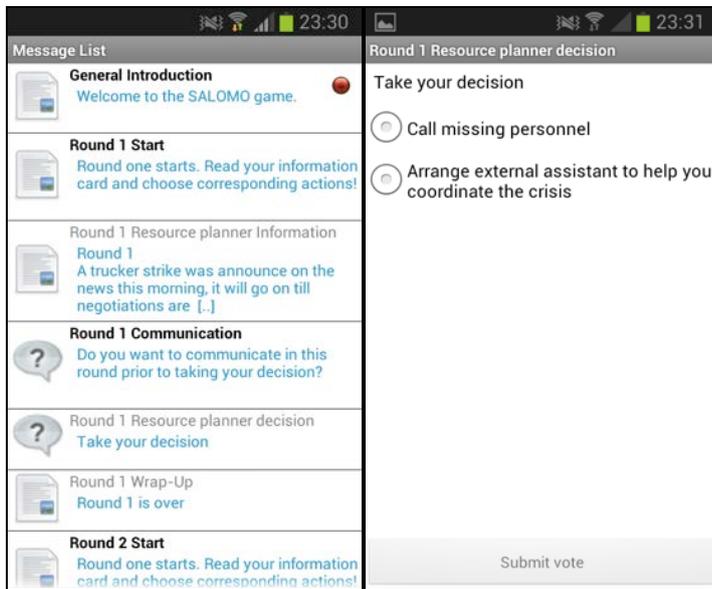


Figure 6. One round of the logistics game-design level two with additional communication phase

Figure 7 displays screenshots of the SALOMO game showing communication messages and decision points.

## 7. COMPARISON

We compare the three game-designs according to the coverage of requirements and according to the role-based game design elements used. **Table 1** summarizes the coverage of the requirements. All cases use a multi-



**Figure 7.** Screenshots of the SALOMO game: message overview and decision point

player, multi-role game-design (R1, R2). Heart Run and the logistics game use the concept of individual information supply (R3), while all games use the concept of event-based notifications (R4). The game is played on standard mobile devices in all three cases (R5). Variations of the game-design are used in the hostage game as well as the logistics game (R6). The logging feature is used in all cases to support the debriefing phase (R7).

**Table 1.** Mapping of requirements to the game designs

	R1	R2	R3	R4	R5	R6	R7
Heart Run	x	x	x	x	x		x
Hostage	x	x		x	x	x	x
Logistics	x	x	x	x	x	x	x

**Table 2.** Comparison of role-based game-design features used

	Heart Run	Hostage	Logistics
Players per Team	>3	3	5
Roles involved	3	3	5
Process	individual	common	common
Information	common	common	individual
Decisions	individual	individual	individual

**Table 2** specifically looks at the use of role-based game-design concepts in the three different cases. The games use three to five different roles. In the hostage taking game and the logistics game these are assigned to one player per role, while in heart run small groups of players can play one role together. Regarding the game process, the hostage taking game and the logistics game have a

similar game process for all roles structured in several rounds of information, events, and decisions to be taken. The game-design of heart run uses individual processes per role, which comprises different tasks and activities to be performed. While heart run and the hostage taking game distribute the same information to all participants, independent of their role, the logistics game makes use of individual, role-based information distribution, where the different participants only receive a portion of the complete picture. In all three game-designs decisions have to be taken on a role-based, individualized basis.

In summary, we could support the three different cases with ARLearn covering the features representing the stated requirements for multi-stakeholder decision trainings. We also asked the game authors for missing features and further requirements in order to further improve ARLearn. In addition to improvements regarding usability issues, the authors asked for further communication features increasing player interactivity and for randomization features, useful to create additional immersion effects, by creating unforeseen effects and events. Random aspects also increase the re-playability of games.

## 8. DISCUSSION AND FUTURE WORK

From three different real world cases, which cope with complex decision situations involving multiple stakeholders, we have derived requirements to model such situations in a multi-user, multi-role mobile game environment. We have designed multi-user games for these three cases and realized them in the ARLearn platform, which covers (among others) the stated requirements for these training situations. We have shown, that the three cases to a large extent rely on the requirements derived, while they still vary significantly in the way the game-designs make use of different role-based features and individualizations ARLearn offers. Consequently, the core contributions of this paper are the requirements gathered for multi-stakeholder decision training situations and their application in the developed cases. Furthermore, we showed that ARLearn meets these requirements and thus appears to be a feasible environment for the design of according games.

While this paper focuses on the technical requirements derived from real-world cases and the game-design flexibility offered in the ARLearn environment, we did not look at the learning-related outcomes here. In all three cases, we gathered first user feedback in small-scale tests, which positively motivates us to continue this work. In depth evaluations for our work are currently designed and prepared. Based on the first feedback, we aim to improve the ARLearn platform and the game-designs applied.

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