Play It Safe; A Situational Game for Occupational Safety

Bard O. Wartena, Derek A. Kuipers and Hylke W. van Dijk

Abstract This chapter describes the design choices and theoretical constructs that have led to the development of an occupational safety game, going by the name Play it Safe. Play it Safe is a tower defense game that uses situational data collected by employees, during their daily work, to impact the parameters of the video game. These data are gathered through a safety campaign named, Count Yourself Lucky (CYL) to quantify the amount of times employees used the supplied safety technique [Stop, Think, Act, Review (STAR)]. Play it Safe, as a form of situational gaming and as a behavioral change support system (BCSS), through metaphorical re-contextualization attempts to create parameters for similar decision making encountered in the work environment and implicitly reinforce the training of the STAR protocol and conservative decision making. Play it Safe aims to improve employees' situational awareness, creating a shared mental model and bottom–up accountability, meant to improve and align (shared) safety behaviors.

Keywords Occupational safety · Serious games · Situational gaming · Behavior change support system · Situation awareness · STAR

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1 Introduction

Accidents happen; however, responsible employers are constantly attempting to create safer environments by improving measures to diminish the number of mishaps and accidents. The incident frequency rate (IFR), the main measure of safety in industry, varies among sectors, as do the risk factors inherent in certain jobs. Measures to maximize safety (knowledge, skills, protocols, conditional safety structures, and safety interventions) contribute to lowering IFR. Not all companies are proactive when it comes to safety or equipped with ample precautions in the work environment and culture. However, even companies at the top of the HSE culture ladder who have taken ample precautions, have a finite effect on safety (DePasquale and Geller 2000).

Even when equipped with all the right tools in the correct environment, the human factor can be the cause of failure (Reason 1990a); as routine kicks in, vigilance checks out. To bring safety awareness to the next level, serious gaming might prove to be a valuable tool in employees' toolboxes. Serious gaming offers a new and engaging way to demonstrate an adaptive interaction with the immediate relevance of situations and contexts from the work floor. In this way, serious gaming can mix reality with an open practice environment in an emergent feedback loop that triggers the players to have safety, which is forefront in the mind at the moments that warrant vigilance, while improving the safety awareness as well as the safety environment. This all through noticing and registering lapses or slips and their probable causes.

This chapter describes the trials and tribulations of the design and development process of a serious game, named Play it Safe, with the goal of behavioral change toward occupational safety aspects inherent to dynamic high-risk jobs and environments. Part two describes on a short outline of occupational safety trends and related work in the field of serious gaming, as well as a short outline of the focus of Play it Safe. Part two focuses on the design process of and implications of situational gaming, part three focuses on behavior change support systems (BCSS), Stop, Think, Act, Review (STAR), and the surrounding safety campaign; Count Yourself Lucky (CYL). Part four describes the video game Play it Safe the involved gameplay and game mechanics as the goals of the game. The final part discusses the possibilities of situational games and the initial experiences with Play it Safe and the CYL campaign.

2 Safety Matters

After physiological needs, the second step in the hierarchy of needs (Maslow 1943) on Maslow's pyramid is safety. Occupational safety has been a priority in the workplace since the beginning of the nineteenth century. Over the last decade, safety structures placed great emphasize on rule-based and behavior-based safety. This approach is described as Model 1 (Hale and Borys 2013), a predominantly

top–down approach. In Model 1, workers attain knowledge and skills and act as rule-based operators who follow golden rules that are strictly enforced top–down. In Model 2, these same rules apply, however, they are seen as guidelines for the competent professional (Hale and Borys 2013). They are dynamic and rein-forced bottom–up, resulting in safety solutions coming from employees instead of management. Independent of the position of safety in an organization, the safety climate and culture of the company implementing the safety interventions has been found to be a key indicator for the attempted intervention (Hale et al. 2010). In addition to the safety climate and culture, a large part of safety science focuses on conditional safety.

Conditional safety entails making the environment as well as the equipment used as safe as possible. This is realized by providing instructions, use of warning signs and protective clothing, making the equipment and the work environment as safe as possible. The primary cause of error and (near) accidents is the human operator. Therefore in safety science, Human Error (Reason 1990b) modeling, based on the underlying strengths and limitations of the human operator, is used to design protocols, rules, machinery, and overall resilient systems to minimize accidents. Unsafe acts can be divided into execution errors (correct plan, wrong execution) and planning errors (incorrect plan). Execution errors can be divided into slips (attention failure) and lapses (memory failure), planning errors can be either rule-based or knowledge-based mistakes (unintentional decision to act against rules or standards) and violations (deliberate decisions to act against rules or standards). To gain further understanding of human error, Rasmussen (1983) developed the human performance model, consisting of the following levels.

- **Skill-based behavior**: an automatized sensory-motor performance that one can perform without conscious control.
- **Rule-based behavior**: based on stored procedures, gained through experience and learning. It works through recognition, association of state/task and then using the stored rule for the task.
- **Knowledge-based behavior**: when confronted with unfamiliar situations, where explicit thought is necessary to develop a plan, exercise it and see if it works. It works through identification, decision of task, and planning.

The different levels of reasoning can be accessed simultaneously, but are triggered by different aspects of contexts and situations. The mental model that workers have of the situation around them, i.e., Situation Awareness (SA, Fig. 1) (Endsley 1995), and the decisions made depending on that situation, are highly influenced by the performance levels used by the operators. SA came from military aviation (Endsley 1988) but since then has been used and researched in a wide range of contexts and fields. Endsley's definition of SA is the perception of 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). This process is automatic. However, perception, comprehension, and projection of how a situation will evolve, depending on the action a worker is planning to undertake, is vital in planning and undertaking an action. When making the decision to perform

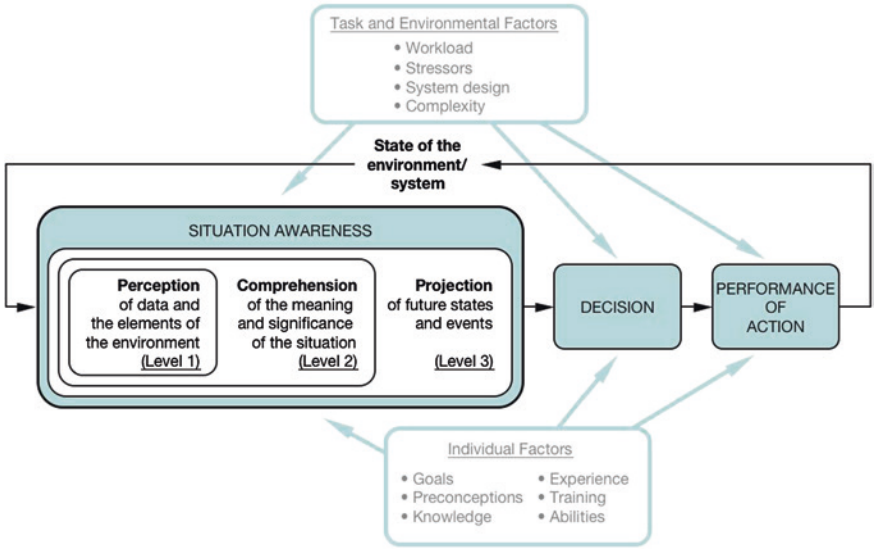

Fig. 1 Adapted from Endsley's situation awareness model [(Endsley 1995), model used from www.situationawareness.nl]

a task, it is vital to base that decision on a correct state of the necessary elements in the environment around you. Therefore, a review of the action undertaken and possible deviations of the projected state of the environment around you are relevant for vigilance and safe behaviors. Besides an individuals SA, there is also Team or Shared SA (TSA/SSA) (Salas et al. 1995; Salmon et al. 2008), the understanding between team members of each other's mental model of the situation. A high level of Shared SA between team members provides a work environment in which the needs and way of approaching tasks and situations of others are understood and taken into account (Salas et al. 1995; Salmon et al. 2008). Therefore, a high SA is a vital part of safety on the work floor, both individually as well as in a team (Leonard et al. 2004) and will produce an increase in workplace safety (Stanton et al. 2001).

2.1 Simulations and Games for Occupational Safety

Games and simulations for occupational safety have been used in a variety of fields with a wide range of goals, including the following:

- Virtual training in construction plants (Guo et al. 2012),
- Virtual training to increase SA during cardiopulmonary resuscitation (Felländer-Tsai 2014),
- Evacuation drills (Chittaro 2012; Maruejouls and Chopinaud 2013; Silva et al. 2013),

- Hazard recognition (Mayer et al. 2013),
- Intervention to reduce work stress and raise work engagement (Wiezer et al. 2013),
- Training and education of operations on ships and offshore platforms (Bruzzone et al. 2013),
- Design in construction (Dawood et al. 2012),
- Training for working at heights for mine sites (Stothard and Van Den Hengel 2010).

These are predominantly simulation games for safety training, depending heavily on a match between content and context, a high level of fidelity and a low level of play (or no play at all). Problems with these simulations are that they:

- almost automatically create a mismatch between the desired blend of entertainment and learning (Ritterfeld and Weber 2006) within the game, missing out on the positive effects of entertainment on learning (Gee 2003).
- require extensive training needs analysis (TNA) methodologies (Bee and Bee 2003).
- can only be used for specific goals and situations. A created scenario within a simulation will only be useful for a specific target group and will only encompass limited tasks and environments. In an occupational safety game, it would be impossible to simulate and program every possible accident or near accident, inherent to the particular task in the particular work sector.

Therefore, instead of focusing on the outcomes of specific risks of specific task-related accidents, the more practical and feasible goal might be to intervene in the mental model an employee applies to approach general tasks, environments, and situations.

2.2 Play It Safe

The Play it Safe project was established to address the needs of several small- and medium-sized enterprises working in high-risk and highly dynamic task environments. Each company faces a similar dilemma; despite specific rule-based behavior and the specific task-related knowledge being available and reinforced, accidents still occurred.

Play it Safe aims at creating top of mind safety awareness for workers in the construction and maintenance industry. The workers operate in small teams with variable constitution and at varying locations. Obviously, these workers know the safety rules, but in the heat of the moment, slips, lapses, and errors occur. Play it Safe focuses on preventing accidents using a cognitive intervention called STAR, for procedural tasks, focusing on the context outside the game rather than the content within the game by the use of situational data retrieved through the CYL campaign.

3 Situational Gaming

Situational games (van Dijk and Voigt 2012) are games in which real-life data are used to affect the parameters of the game, often by the use of cross- and transmedial applications. The idea is to gather situational data and play the game in close proximity or on the location and in the context where the initial problems arose. The basic assumption of the effectiveness of a situational game for serious purposes is that situation provides an authentic setting that engages a player, helps to realize the logic, and triggers the player into action. The authenticity provides the necessary meaning and appreciation. The situation plays a role in multiple dimensions of persuasion, i.e., striving to persuade players to change their behavior. The framework helps to make the role and possibly the impact of situation explicit during the design of serious games. Situation contributes in a positive way in reaching the underlying objective of the game. For Play it Safe, situational gaming was used to attempt increase safety awareness among workers. Eventing, thus taking real-life events into the gameplay, is suggested to be a good starting point for any situational game (van Dijk and Voigt 2012). Situation and context determine the effect of a trigger. Triggers, when carefully timed and chosen, provide the spark to activate a change in behavior (Fogg 2009). By adhering to a person's situation, triggers become authentic and actions become meaningful (Salen and Zimmerman 2005). The player can identify itself with the matter.

The use of situational data in Play it Safe reflects the belief that transfer should be considered as a design parameter. Kuipers et al. (2013) argue that core principles (in this case the STAR protocol) in a game should be carefully designed in conjunction with a specific transfer type in mind, aligning the players' needs and abilities, including sociocultural aspects, serious goals, and topic characteristics. The process of translating situational data into game elements is called re-contextualization, defining the pinnacle of serious game design: The subjective soundness and recognize ability of the re-contextualization is essential for transfer of safety awareness. By introducing real-life data in the game, they link the target context to the learning context (the game), enabling transfer between similar, but not identical contexts.

Near transfer can be categorized under literal transfer: transfer by the means of similarity, as opposed by figural transfer: transfer as a result of using some part of existing world knowledge for thinking about a particular problem. The game transfer model projects a game as a conceptual continuity in a continuum, stretching from mimetic simulation to abstract gameplay (see Fig. 2). Within boundaries, the position of the game on the game transfer model (Kuipers et al. 2013) has to correspond with design choices dedicated to facilitate transfer in a situational game aiming at raising safety awareness among employees through re-contextualization of the STAR protocol and situational input.

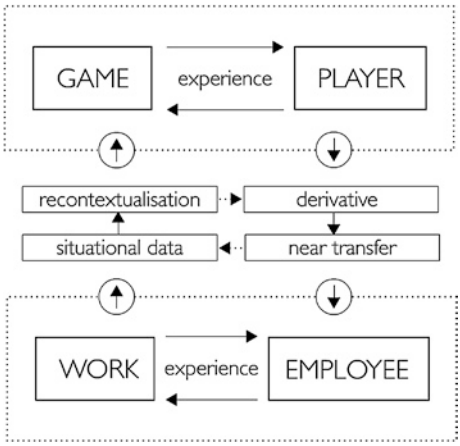

Fig. 2 This model describes the desired transfer model of the game and the reality outside the game as experienced by the player

4 Behavior Change Support System; Count Yourself Lucky with STAR and Play It Safe

A BCSS was defined by Oinas-Kukkonen (Gemert-Pijnen et al. 2013; Oinas-Kukkonen 2013) as:

> a socio-technical information system with psychological and behavioral outcomes designed to form, alter or reinforce attitudes, behaviors or an act of complying with-out using coercion or deception.

The computer game Play it Safe is not a stand-alone intervention, to be a BCSS, it needed a transmedial function (Dena 2010) as a trigger to create the situational input and a complementary tool for assessment and participation to gather this input. Through the project, state-of-the-art sensors, and other elaborative options were proposed; however, they proved to be infeasible in a highly dynamic high-risk work environment. Many companies, for instance, did not allow smartphones because the digital disruptions could prove dangerous during working hours. Therefore, an analogue solution was found.

4.1 STAR: Stop, Think, Act, Review

Play it Safe uses the safety intervention STAR combined with situational aspects, i.e., events from the work floor are integrated to have effect in the game. STAR is a mental protocol to facilitate safety awareness. This mental protocol attributes the creation of awareness of a situation to three entangled processes: perception, comprehension, and projection. These processes attribute the enclosing environment, the physical context. The mental model is completed with a decision-making process and an effectuation of an intended action. The action obviously affects the

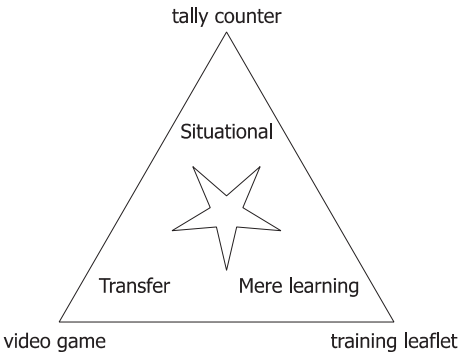

Fig. 3 The ubiquitous workings of the STAR protocol as a. a situational safety detection tool, b. a game mechanic, and c. the textual intervention

state of the immediate environment. STAR is being and has been used in several fields (Dickerson et al. 2010; Paradies 2007; Yates et al. 2005) and is closely modeled on SA (see Fig. 5).

STAR has different modes of use (see Fig. 3):

- as a **standard protocol** to be used with every task (*skill-based behavior*)
- as a **critical task protocol** to be used only with tasks that are deemed to be a risk and require full attention (*rule-based behavior*)
- As an **emergency protocol** to be used when something goes wrong and one finds him/herself in an unfamiliar situation (*knowledge-based behavior*)

4.2 Count Yourself Lucky with STAR

In the implementation of Play it Safe, STAR was utilized and integrated in all of the aforementioned modes. STAR was also used to detect deviations from the projected outcome of situations and record these with a tally counter (CYL), and that amount was then used as an in-game reward. During the Play it Safe campaign, STAR was used as a safety protocol and detection tool in the workplace (see Fig. 3):

- A **safety protocol** to use while performing critical tasks and after some practice become part of skill-based, rule-based, and knowledge-based behavior. This was attempted through mere learning on a leaflet and demonstrations.
- A **detection tool** for situations that deviated from the projected outcome of an action (through the Review in STAR), of oneself or others. These deviations where used as the input of the CYL score, keeping score daily on a tally counter.

The motivation to use one's tally counter in the CYL campaign (besides bottom–up accountability and communication culture) is to gain an in-game advantage. Through the use of an electromagnetic pulse (EMP) in the game that makes it possible to progress with more ease in the game. The EMP, however, is a

re-contextualized STAR protocol that lets the players do two essential things, in the game:

1. **Assess** when the in-game situation becomes too dynamic to project a clear outcome, i.e., being unable to project the situation state after the action is undertaken.
2. While using the EMP, players are forced to **Review** the situation and reorder the elements in the situation and the appropriate actions that can resolve it.

The ubiquitous implementation of STAR (see Fig. 3) trains players outside of the game to use a mental protocol to integrate into their daily working behavior, while at the same time acting as a detection tool for situations that deviate from their projected outcome. This facilitates the players to take a closer look at their daily working environment and the boundaries to work safely within them, as well as noticing the limitations or shortcomings of conditional safety structures. The CYL campaign is motivated by the in-game reward system, while in the game the STAR reinforces the already learned protocol in unrealistic situations that train the players SA.

Because the video game is played during lunch breaks in the workplace, the situations become more tangible and the implementation of the CYL score can become a trigger to discuss workplace safety among colleagues. Furthermore, because all colleagues are using the same protocol, the Shared/Team SA is trained and barriers in individual SA can be discussed as requirements for a high Team SA, creating an open communication culture where bottom–up initiatives are harnessed.

5 Play It Safe: The Computer Game

Play it Safe (see Fig. 4) is a touch screen tablet-based video game of the tower defense genre, the objective of a tower defender is to protect ones base against an enemy that wants to steal the supplies stored in that base. To succeed in this objective, the player builds towers, tactically placed around the area to kill the stream of enemies. Play it Safe differs from traditional tower defense games, with the addition of workers that build and fix the towers and the possibility to use an EMP as a strategic advantage. The story behind the game is that a spaceship has crashed upon a distant planet that is inhabited by bug-like aliens who are attracted to energy cores that you need to power and repair the ship. To defend the crew and ship against the bug-like aliens, guard towers are built that automatically shoot the bug-like mechanized aliens.

5.1 Gameplay

When the player starts the game, he/she can build as many towers as time allows, before a first wave of enemies arrives. The arrival of enemies is usually preceded by an alarm, but as with any action in the game, there are exceptions that keep players

Fig. 4 A screenshot of Play it Safe being played

on their toes. Towers are built by workers, when chosen workers have a primary objective to build, towers will be finished quicker. When towers are built, workers can be placed in the towers so that alien robots will not hurt them. After or during these attacks, they can be directed to fix broken towers; however, there is a risk they will get hurt. Enemies approach in waves, so usually there is time after a first wave to regroup and fix or build extra towers. During waves, pressure builds and it gets harder and harder to keep control over workers while keeping track of the states of the environment as well as enemies. It is possible to use the EMP mechanic to regain control over the game environment and regain situational leadership over the workforce. If the player keeps the energy cores in the game, he/she wins, if the player loses all of them he/she loses. Extra points and badges can be won for using workers for their primary objectives, using the EMP and not letting your workforce get hurt.

5.2 Game Objects

Energy Cores

The energy cores are the main assets in the game. Workers try to defend them and the enemies attempt to steal them. They are kept in the base spaceship.

Base
The home base of the game avatars is a spaceship wherein the energy cores are stashed. Members from the workforce enter the game through the base when the player starts to build towers.

Enemies
There are two kinds of mechanized bug-like aliens. Both types can steal energy cores; however, the eaters will attack towers and workers on their way to steal the cores, whereas the collectors will go straight for the energy cores.

1. **Eaters**, their main objective is to destroy towers, by gnawing on them.
2. **Collectors**, their main objective is to walk into the base pick up an energy core and walk away with it, toward their own base.

Workers
To create towers, it is necessary to have workers to built and restore the before-mentioned towers. There are three types of workers.

1. **Builders** build and repair towers.
2. **Firemen** extinguish towers when they are on fire.
3. **Mechanics** fix mechanical damage in the towers.

The player can distinguish between the three types by the visual appearance of the workers. Their entire workforce has a single primary objective as well as a fitting suit to perform this primary task. It is possible to assign tasks to avatars that are not their primary objectives; the avatars will, however, be slower and less successful in performing these non-primary tasks and thus in more danger. When either fire, radiation from a tower or an enemy hurts a worker, their health state declines and they eventually die. To heal workers, they can be directed into an undamaged tower, where they will be healed.

Towers
Before building a tower, the integrity of the ground to be built on must be checked. The higher the integrity of the ground, the more resilient the tower will be against enemy attacks. Towers can be placed anywhere on the map and shoot intruding enemies on sight. Whenever enemies damage towers, their states deteriorate and markers (electricity sparks or fire) are visible before they eventually collapse or are repaired. The workers can hide in the tower from enemies closing in on them.

5.3 Game Mechanics

Count Yourself Lucky score
The player is asked to fill in the day score of the previous working day on the start screen of the game. This score is used to determine the amount of EMPs available to the player in the game.

Ground inspection
To build towers, the integrity of the ground can be checked with a special option to use a looking glass that gives the percentage of the ground integrity. This influences the towers deterioration process.

Electro Magnetic Pulse (EMP)
The EMP can be used either to freeze all enemies as well as workers or to just freeze their enemies, depending on successfully using the touch screen hold mode on the intended icon. In either situation, it gives the player time to use STAR and gain a new oversight in the game, which can be lost due to the pace in the game.

5.4 Transformational Learning

Through the use of metaphorical re-contextualization (Fogg 2009), Play it Safe uses near transfer to create a metaphorical low-fidelity game world in which less explicit and extensive parameters apply in comparison to the workplace. In the Game world, there are observable (enemies) and non-observable (ground integrity) threats as well as simulated time pressure, which forces the players to keep reassessing their plans and actions with regard to the ever changing the environment. Not to recognize specific or realistic threats, but to gain insight and perspective on the need for an oversight into the aspects of a situation, i.e., situation awareness and the necessity of conservative decision making within a dynamic environment (Fig. 5).

Mitgustsch (2011) distinguishes three stages of learning through serious games aligning with Bateson (1972) stages of learning; (1) in, (2) through, and (3) beyond the game. In case of Play it Safe, the transformational learning process is as follows:

- In the game, the player carries out random tasks at hand and leads a workforce that can change into various states. Through trial and error, the player reacts to the game environment and learns to play the game.
- Through the game learning, the player will learn what the limits and barriers of their situation awareness are and when they reach these parameters.
- Beyond the game learning, this stage is expanded to real-life contexts outside of the game. The player recognizes the barriers for high situation awareness in their daily working environment and is continuously training the use of STAR in skill-, rule-, and knowledge-based behaviors to reduce errors, slips, and lapses and ultimately the companies' IFR.

SA and STAR are used to overcome the in-game challenges without being explicitly taught, creating an implicit training tool. Play it Safe the computer game combined with CYL and the explicit STAR training, together function as a transmedial BCSS that attempts to abide by the dynamic demands of the sociotechnical environment.

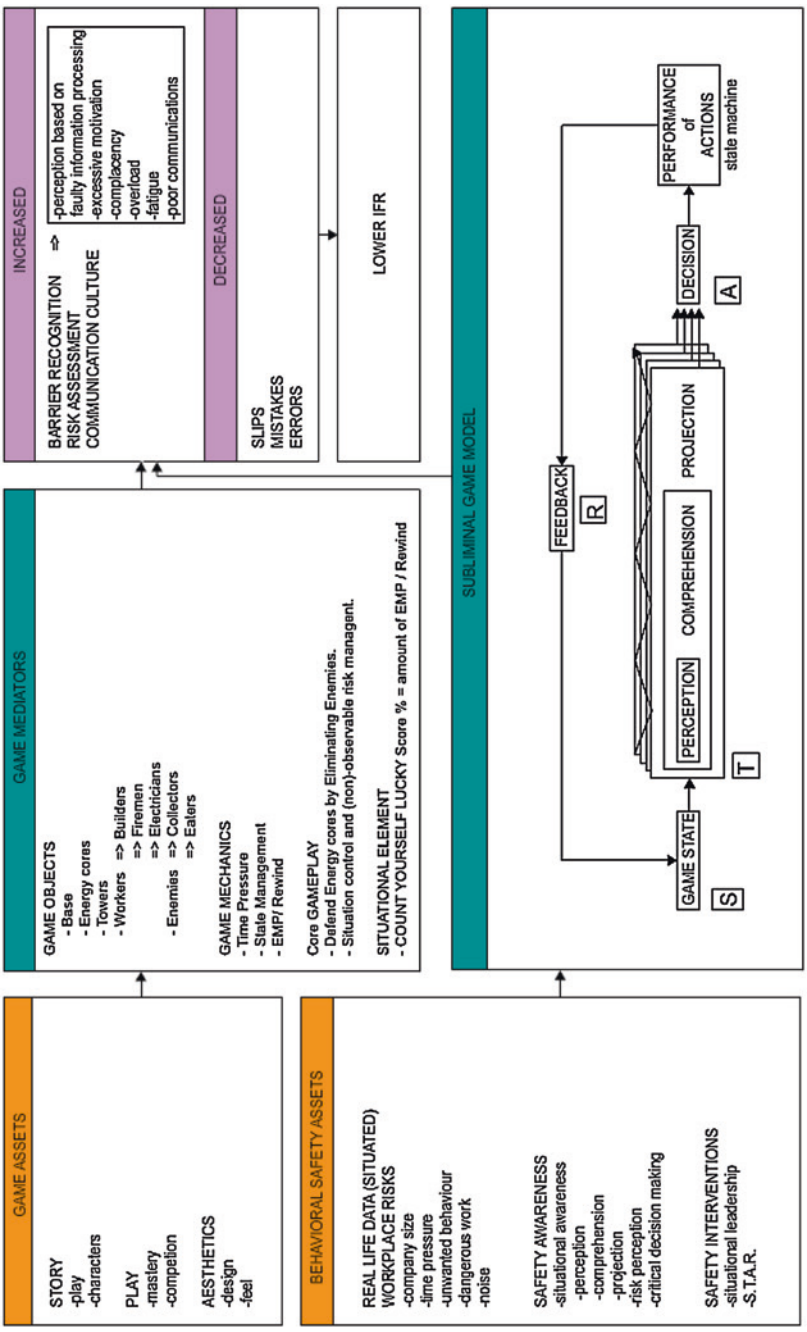

Fig. 5 The proposed schematic behavior and attitude-changing model, adapted from Thompson et al. (2010)

6 Discussion

Because of the ubiquitous nature and transmedial character of the BCSS, a schematic breakdown of the active elements is given. Play it Safe implements four modes of use (Wartena et al. 2014) of one BCSS through situational gaming:

- As an intervention, STAR is implemented to attempt to improve individual SA and Team SA. Through the use in and outside of the game, the recognition of a loss of overview or cognitive overload in working situations is trained and reinforced.
- As a trigger, through the use of the CYL campaign, wherein the employee, through the use of a tally counter, keeps track of the situations in which he/she lost the overview of the situation.
- As an assessment, for employees and safety leaders through the scores of the game, as well as the individual or shared CYL scores, which both act as a self-assessment and give feedback about the amount of unsafe events on the work floor.
- As a tool for participation, through the CYL campaign empowering users to inform safety managers about unsafe practices, equipment, behaviors, or specific situations or context.

This transmedial BCSS aims to impact compliance toward safety rules, lasting behavior change through creating a Team SA by using the mental protocol STAR and ultimately an attitude change in creating a bottom–up safety culture, making safety a tangible concept that all members of a team are involved in and feel accountable for.

Play it Safe harnesses the motivating and rewarding aspects of in-game appraisal for out-game actions (CYL), as well as implicitly reinforcing the actions outside of the game, in the game itself. Thereby, Play it Safe can be considered a recursive BCSS, not to create high vigilance at all time, but to recognize the barriers inherent to an incomplete view of a situation. Performing knowledge-based behavior while wrapped up in other tasks can be dangerous at any time (Verwey 2004); therefore, an insight into the precursors of cognitive overload can be a powerful tool for safety awareness.

In the preliminary trials, safety leaders, on site of the respective companies, noticed an increase in interactions and respective tally counters scores when group activities took place than when solitary tasks were performed. The CYL campaign seemed to increase the communication culture concerning safety matters during these group activities. The simple task of making a conscious note can be a tangible trigger to enhance situated cognition through situated play (Rambusch 2006). As a situational game, Play it Safe makes the environment the trigger in and outside of the game, utilizing safety on the work floor through the game.

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