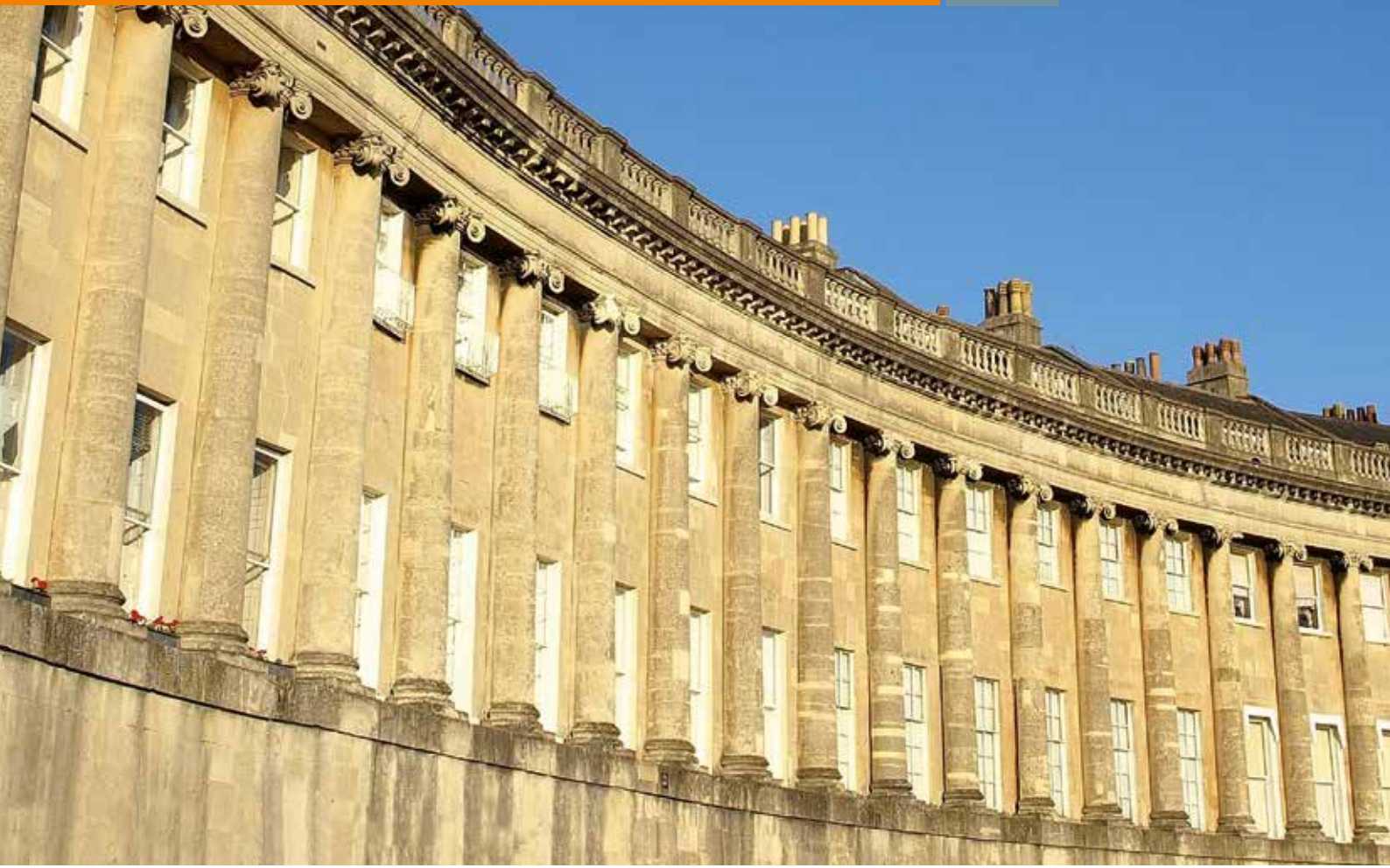# NATURALISTIC DECISION MAKING AND UNCERTAINTY

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Training support for Naturalistic Decision Making: Serious gaming for adaptive performance of military personnel

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ABSTRACT

Introduction: For effective decision making in the 21st century where operational environments are complex and uncertain, there is a strong need for training support and its practical application to naturalistic, real-world settings. In this contribution, we focus on training of adaptive performance using NDM approach. In particular, we introduce serious games (SGs) as a potential means to train adaptive performance of military personnel. **Method**: The design of our SG is explained with the aim of enhancing adaptive performance and effective decision making in complex and uncertain environments. The rule change element is introduced and other game design elements are described taking the perspective of Naturalistic Decision Making (NDM) approach. **Results**: The findings from a game design validation session show that participants were able to assess the situational change and adapt their actions during the SG play. Challenges of practical application of the training support into the Dutch Major's school are described. **Discussion**: We discuss future directions of SG improvement within an NDM approach.

KEYWORDS

Decision making; adaptive performance; education and training; serious game; military.

INTRODUCTION

The Naturalistic Decision Making (NDM) approach has been frequently examined and applied in various domains, especially the domain of defense and security (i.e., Klein, Klein, Lande, Borders, & Whitacre, 2015). Effective and efficient decision making of commanding officers not only affects their own work performance but also the lives of soldiers and civilians. Incidents such as the USS Vincennes shooting down a commercial airliner in 1988, the Tarnak farms incident where American F-16 bombed Canadian soldiers in Afghanistan in 2002, and the attack of an Afghan hospital by the US military in 2015 show that decisions made under time pressure and with incomplete and often conflicting information can have adverse consequences. Therefore, many scholars have investigated decision-making in real work environments to help high-stake decision makers in various domains including the military. However, sound decision making in the 21st century involves several challenges because operational environments are becoming more complex, changing, uncertain and unpredictable. To effectively handle such environments, adaptive performance, defined as a capability to change and adapt according to situational demands (Good, 2014), should be enhanced. Despite the need for training professionals in decision-making under uncertain circumstances, there has been a scarcity of research into the development and application of such training support tailored to real working environments. This study aims to explore the game design of training support for ill-structured decision-making in uncertainty to enhance adaptive performance of future commanders from the perspective of an NDM approach.

Coping with uncertainty

According to Lipshitz and Strauss (1997), 'uncertainty' is summarized as *ambiguity*, *doubt*, and *unpredictability* causing difficulty to make sound decisions. The topic of uncertainty management has been studied in various domains such as education, cognitive psychology, and human factors using related constructs. For example, the term 'adaptive performance' refers to adaptability in real-time task performance under uncertain and dynamic circumstances (Good, 2014). In that sense, 'cognitive flexibility' is one of the strong predictors of adaptability, viewed as an adaptive reaction to changing and uncertain situations by rapidly reforming one's knowledge (Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). Another related construct to uncertainty management, 'resilience', refers to human and system interaction under complexity and uncertainty (Bergström, van Winsen, & Henriqson, 2015). Finally, 'accelerated learning' shares similarity with uncertainty management in that the aim of accelerated learning is to enhance work proficiency dealing with complexities including uncertainty (Hoffman et al., 2014). Scholars have investigated uncertainty and its related constructs to understand and improve human

performance despite the challenges of complexities and uncertainties. As earlier research of uncertainty management focused on acquiring more information before the moment of decision making to decrease the level of uncertainty (i.e., Lipshitz & Strauss, 1997), more studies nowadays emphasize the exposure and experience to decision making under such challenging operational environments to better deal with uncertainty (i.e., Carbonell, Stalmeijer, Könings, Segers, & Merriënboer, 2014) rather than ways to avoid or diminish uncertainty. Although many researchers examined how people make decisions under uncertain and complex situations, as Klein (2015) expressed his concerns, more studies should focus on training methods and their applications, which can aid effective decision making under uncertainties and complexities that are realistic and hold direct implications for the workforce. Therefore, we will introduce a design of a training support for adaptive decision making of military personnel.

Training support: Serious gaming

We introduce Serious Games (SGs) as a potential training means to support adaptive decision making of military personnel. SG refers to a class of games used for the purpose of learning and training beyond entertainment (Ritterfeld, Cody, & Vorderer, 2009). With technological advancement, numerous scholars have investigated SGs as an alternative learning tool for education and training. In particular, SGs have been frequently studied for workforce training in domains such as medicine (i.e., Graafland, Schraagen, & Schijven, 2012), business (i.e, Chang, Chen, Yang, & Chao, 2009), security and safety (i.e., Nesbitt et al., 2015). Also, SGs are widely used in dynamic decision making research (i.e., Gonzalez, 2004). For training of adaptive performance within the NDM perspective, SGs may be a valuable tool in that it offers a naturalistic environment where learning is situated in context (Gee, 2005). Considering that scholars have emphasized the instruction method of exposure and experience to operational environments that are challenging due to complexity and uncertainty (Spiro, Coulson, Feitovich, & Anderson, 1988), SGs are a practically suitable means to provide naturalistic virtual environments where dynamic, novel, and complex decision making can be practiced. Furthermore, using SGs as a training support for the military seems valid because of its time and cost effectiveness in comparison to traditional field training (Roman & Brown, 2008). Finally, SG is a familiar training means to military in that SGs are commonly used for military training for over 200 years.

Previous studies focused on training adaptive performance using SGs. Cañas et al. (2005) investigated the efficacy of strategy change during SG training, which encouraged dynamic decision making under changing environments. Glass et al. (2013) examined SGs—embedded within a rapid switching and dynamic virtual environment inducing complex decision making—as an intervention to increase adaptive performance. Gonzalez (2004) examined the relationship between time pressure, cognitive abilities, and dynamic decision making using SGs in uncertain and changing environments. Other studies (i.e., Chen, Thomas, & Wallace, 2005; Good, 2014; Marks, Zaccaro, & Mathieu, 2000; Stokes, Schneider, & Lyons, 2010) investigated SG support for adaptive performance embedding complex decision making tasks under changing and uncertain environments. These studies hold value in that they reported training outcomes to better aid adaptive performance and they used realistic decision-making tasks via SG support. However, direct application of these studies into real work training is somewhat limited in that all of these studies used university students as participants in controlled laboratory settings, hence taking a microcognitive rather than a macrocognitive perspective. Therefore, SG design within an NDM approach may further facilitate the practical applications of SG training support for the adaptive performance of military decision-making.

METHODS: GAME DESIGN

In this section, we will address the theoretical foundation of the SG and how the SG was designed to enhance adaptive performance via rule change element. We will first describe the macrocognition (Klein et al., 2003) and the recognition-primed decision (RPD) model (Klein, 1993). These concepts are theoretically embedded in the game design as their relevance to adaptive performance in uncertainty. Then, the specifics of the game design will be described.

Macrocognitive functions and processes

Macrocognition refers to research on functions of cognition and how these interact within realistic environments (Schraagen, Klein, & Hoffman, 2008), including Naturalistic Decision Making. The rationale of using macrocognitive functions to explain the game design is that the definition of macrocognition is closely related to adaptive performance in complex, naturalistic environments. Therefore, we will describe our game design as aligning with the description of macrocognition by Klein et al. (2003).

- Naturalistic decision making; complex decision; decision making under time pressure, high stakes, high risks: The game is designed for naturalistic decision making in that players (role of company commanders) have to make decisions in a military relevant context such as sending units to gather intelligence, to find civilians, order to capture enemy intel, etc. Players make complex decisions due to an abundance of information, lack of information, changing situations and unknown situations. Players are limited to take only two actions per case and the narrative requires players to take rapid actions within a particular time

limit. Risks are high because units can be heavily damaged and cause a death toll depending on the decisions made.

- Planning-> sensemaking and situation assessment-> problem detection-> adaptation and re-planning:
  These are the attentional processes that we expect players to experience during the game play based on their prior working experience. After the briefing, each player plans how to tackle the problem. As players make a series of decisions via cases, sensemaking and situation assessment occur. For example, players gather situational cues such as the interaction of decoys with mounted enemy weapon. Then, players assess the situation based on the decoy that when approaching the pathway, the mounted weapons near the pathway detect and destroy all air and ground vehicles immediately. Sound decision based on the situational assessment will be sending the units on foot where the radar of mounted enemy weapon cannot reach. We embedded situational cues throughout the narrative in a way that the number of cues increases gradually for effective training, avoiding data overload. During the rule change phase, players detect problems in that how they previously made decisions no longer applies to the changed situation. In this phase, the feedback they receive contains results of actions following the new situations. For example, the mounted enemy weapon no longer detects and destroys the air vehicle due to the malfunction of its radar after the solar eruption. For course, the causation between the solar eruption and malfunction of enemy detection radar is not explicit. It is the role of players to assess the change of situations and conduct appropriate sensemaking. Therefore, in order to complete the mission successfully, players must adapt and re-plan according to the new situation.

- Vague key variables, goals and their interactions; uncertainty management:
  The narrative contains various unknowns such as no available intelligence on behaviour of enemy robots, missing information on the map, and the rule change. No players are told that rules change in the narrative. Players have to detect the changes based on given situational cues and feedback and adapt accordingly. Feedback is given only as a course of chosen actions instead of showing which options were the best. Players have no information about the long-term effects of decision making in each case. Therefore, the game is purposely designed such that players are exposed to complex decision making under uncertainty.

RPD model

In this section, we will examine the game design following the aspects of the RPD model, which is an aspect of NDM. The rationale of using RPD model is due to its strong relevance to the goal of game design and its training application for naturalistic decision making support.

- Four aspects (plausible goals, relevant cues, expectancies, actions) of situation assessment:
  As we mentioned in the general description of the game design, the selection of two decisions out of four actions is not designed to judge the options and select the best one. Instead, the focus is on decision-making based on situation assessment. First, players are informed about the goals of the mission (i.e., rescuing civilians, gathering intelligence on new robot army) and they are plausible in that players have resources such as units and advanced technology to achieve the goals. Second, relevant cues are embedded in case descriptions and feedback. Third, there are expectancies that players (trained military personnel) can complete the mission by successfully rescuing the civilians and defend the area against the enemy. Fourth, players take courses of action (i.e., sending the combat unit to a housing area to search for remaining civilians) based on their situational assessment.

- Three levels of decision making:
  During the rule learning and consolidation phase, the level of decision-making is designed to be simple and more complex as players proceed. The level is controlled by the amount of information processing for effective decision-making, amount of relevant cues and available information. The control of complexity and gradual presentation is critical for effective training, avoiding overload of complexity (Field, Rankin, Pal, Eriksson, & Wong, 2011). When players enter the rule change phase, the level of decision-making is at the most complex due to the unexpected and uncertain changes of the situation.

- Conditions of using RPD model:
  This game is designed to support decision making of military officers. We expect that the ideal users for this game have sufficient working experience in military service. The available data in the game is rather perceptual and intuitive in terms of relevant cues and feedback in that no statistical or numerical data is provided for affecting decision making. We emphasize the adaptive performance during the rule change phase but not on the justification of the decision making in general. In fact, the game does not provide feedback whether one decision is better than another. Also, the decision tasks are ill-defined and high level without structured, psychomotor action. Ambiguitiy is prevalent throughout the narratives and players have to deal with uncertain, unpredictable and complex situations. Due to the rule change, the situation is unstable.

We designed and developed a PC-based, complex decision-making SG, using the theoretical perspective of NDM approach as explained above, to increase the implication of the training tool for military training of adaptive performance. The game is scenario-based, designed for individual players (military personnel) with a rich

narrative. Two scenarios are created following the game design framework (see Figure 1). For each scenario, players (decision makers) begin the game with the briefing, which contains the goal of the game, background information, and the current situation. Players complete the game by making 21 decisions (cases) following the descriptions of cases in each scenario. A case refers to an assignment for players. Maps were added in the game to help players visualize the location. Decision making in the first nine cases is the rule-learning phase, where players learn about the situation and three main rules about the virtual environment (i.e., behaviors of the robot enemy). Following each case description, players receive four different actions. Once players choose two actions, feedback is given automatically about the results of chosen actions (see Figure 2). For instance, a player (a company commander in scenario 1) can select two actions among a) Send a combat platoon unit to a nearby 5-story hospital building to search for civilians, b) send out armed scouts to a nearby water treatment facility to gather intelligence, c) send out armed scouts to a nearby warehouse to gather intelligence, and d) Send a combat platoon unit to a nearby bus station to search for civilians. Such selection is geared to encourage learning by doing and feeling of control as a player rather than weighing the best option. After the rule-learning phase, a second briefing is given with more information. Afterwards, players confirm the rules during the consolidation phase. This phase is created with the purpose of reassuring learning in case players did not understand the rules initially. Finally, an event occurs that changes the initial rules during the rule-change phase. For example, a solar eruption occurs changing the functions and behaviors of enemy robots in scenario 1. The players are not told that the rules are changed. They have to figure it out by themselves based on the decisions they make and their feedback.
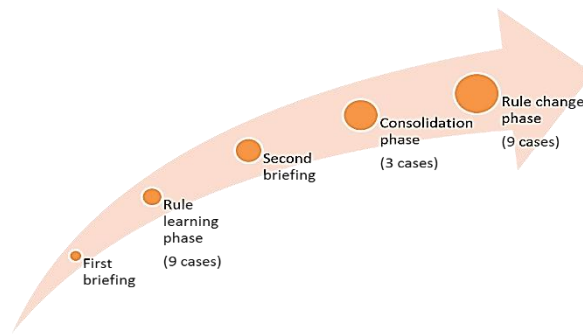

Figure 28. Game design framework

The key game design for supporting adaptive performance is the rule change phase. Rule change is our main game element that is designed to expose players to an adaptive performance-inducing environment. The rule change element is derived from tests, which measure cognitive flexibility (i.e., Wisconsin Card Sorting Test). Naturalistic and situated context is added to the rule change element, which is tailored for military decision-making. Our assumption is that by providing a naturalistic experience of rule change via a strong narrative, military officers can enhance adaptive performance leading to effective decision-making under complex and uncertain situations. The further details of game mechanics are available in the Mun et al. (2016) study.

Figure 29. Action- and feedback-based game play

RESULTS

As our study is in work-in-progress status, we will share the brief findings regarding the practical application of the training support for enhancing adaptive performance. First, we tested the SG whether the discussed design of the SG induces expected behaviors of players such as detecting the rule change and adapt their planning for effective decision making. After the initial testing, we improved the game and used the game in the military training as a pilot study.

Validation of SG design

Before the validation, we improved the game based on the feedback from playtesting done by SG experts at TNO. Afterwards, we validated the game design during an introductory workshop for Game Master's students at the University of Amsterdam. The rationale of using student participants although taking an NDM approach is that these students have extensive experience and knowledge in games. Therefore, we assumed that these participants can provide us more insights on improving the game prior to its application in military training. Twelve Game Master's students (1 female, 11 male) participated in game testing. We introduced the purpose of the game testing and general instruction on how to play the game. At the end of the game play, students filled in a survey and informal group reflection was given. The total testing took about 90 minutes.

From the testing, we found that individual differences of players are strong in terms of time of game completion, and decision making patterns. Out of 12 participants, 11 participants reported that they were able to detect the rule change and acted accordingly. The moment of detection varied per player. The survey investigated how the players experienced the game. It consists of students' ratings on game difficulty, level of engagement, motivation, and concentration as well as open questions for suggestions. Figure 5 shows how the participants experienced the game. Both engagment and motivation was positively reported. Concentration and difficulty varied among the students. Some participants expressed during the group reflection that making decisions in military context was difficult due to their lack of prior knowledge. For concentration, some participants mentioned that they were distracted due to fatigue. In fact, this session was given at the end of the introductory workshop, which lasted 9 hours. Based on the suggestions and feedback from participants, we modified the game such as adding more visual aids and modifiying parts of narrative.
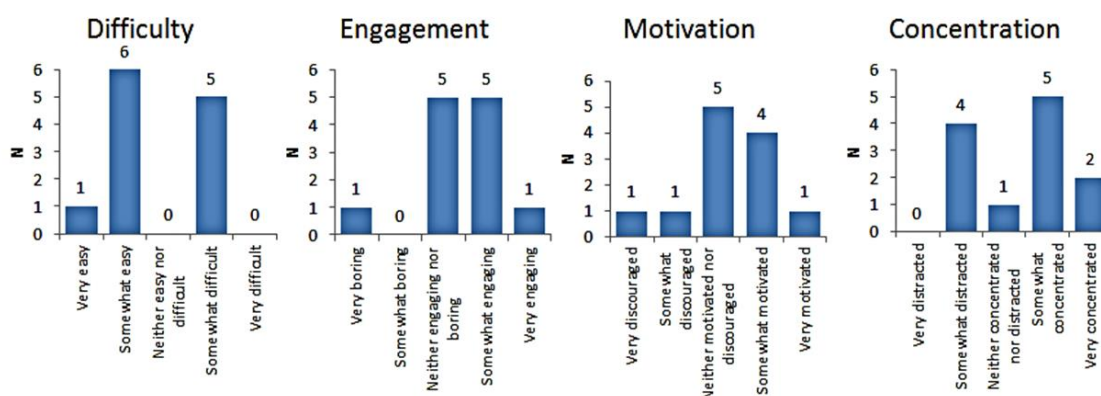
Figure 30. Students' assessment on the game testing

Application to military training

After the revision of the game, the game was used in the military training during the Dutch Major's course. Seventeen Major's course students (military officers) participated. The session began with the purpose of the training followed by the introduction to the game. The officers played the first scenario in the morning session and the second scenario in the afternoon session. Each game session contained individual and group reflection upon completion. In between the game play, participants were asked to fill in questionnaires and participate in non-game adaptability related tasks. From the notes taken during the reflection session, we conclude that the application of the game for adaptive performance was positively received by the participants. However, challenges of applications into a real military training setting occurred. Besides the technical challenges, some officers felt discomfort with the changes in narrative. Although many officers found the SG as an interesting training tool for adaptive performance, others had difficulties accepting the scenarios as the narrative with the rule change conflicts with their prior knowledge and experience. The data analysis is currently in progress.

DISCUSSION

This study explored the game design to support the training of adaptive performance in a naturalistic decision-making context for military personnel. We introduced rule change as a design element to induce adaptive performance. Then, we explained the game design using the macrocognitive functions and processes described by Klein et al. (2003). Moreover, we described the SG design in terms of the aspects of situation assessment as well as levels of decision making and conditions of the RPD model (Klein, 1993). Following the SG design, we reported findings from a game testing session and application of the SG in the Dutch Major's school training.

Although the game design contains various elements encouraging the abovementioned training aspects, it is important to actually check that players train adaptive performance via those game elements. For example, some players from the game workshop responded to the questionnaire in that they did not feel the time pressure although it was embedded heavily in the narrative. Considering that one of the NDM conditions is high time pressure, the

addition of another game element for time pressure might be necessary. Another issue is the conflict between players' prior knowledge and the training context for adaptive performance. From the military training, we observed that some officers felt confusion and discomfort due to the rule change. This concept of training is new for military personnel and some confusion is inevitable as the officers have strong prior knowledge on the military context. Therefore, we should further investigate on the state of players' knowledge structure during the SG play and the effects of strong or weak prior knowledge on the military context. In terms of immersion, we received overall positive feedback from both military officers and game students that our SG training tool is engaging. However, it is difficult to check whether players use balanced intuition and analysis in their decision making as Klein (2008) emphasized. As the two pilot sessions were focused on the validation of the training concept and its application, rather than embedding RPD model to the testing, future research should pay specific attention to measuring macrocognitive functions to assess the effects of the SG using NDM approach. Moreover, how the RPD model cognitively takes place within the decision making during SG play such as mental simulation should be examined in detail. Also, more attention should be paid to other design elements that can train adaptive performance. Lastly, a more empirical study should be conducted to examine whether the developed SG can effectively train and improve adaptive performance of decision makers.

ACKNOWLEDGMENTS

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