Improving military Crew Resource Management using a commercial strategy game

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ABSTRACT

Crew Resource Management (CRM) training has been among the staple diet when addressing Human Factors within military aviation, both in the initial and recurrent training phases. In recurrent training, CRM modules traditionally focus on creating awareness of the role of non-technical skills such as decision making in safe operations. While awareness can be successfully raised by CRM courses, actual change of non–technical behavior is still a challenge. Military aviators often claim it is difficult to implement the theoretical aspects of CRM training in practice. Therefore, a solution is needed where non-technical skills can be applied in a relatively rich way, including team aspects and time pressure, to create situations where human factors issues may be experienced and trained. At the same time, the solution is subject to many constraints: it needs to be short (to fit into a regular CRM training day), cost effective and easy to use.

To address this challenge, the potential of commercial video games was evaluated empirically. Based on the CRM training module, a 'suitability analysis' was performed on a range of different commercial video games, decomposing the different game elements of each game. Resulting from the analysis, a training solution using the game "XCOM – Enemy Within" was developed. This training solution was subsequently applied in a CRM training course. Using video recordings, team and individual behavior have been analyzed thoroughly to identify the game's potential for producing CRM behavior as well as effect on dynamics of group behavior and decision making.

Key training effectiveness evaluation points included depth and variety of challenges posed by the game, trainee potential to implement CRM and instructor possibility to evaluate CRM behaviors. Results indicate the game is effective in developing CRM behavior in trainees and leads to sufficient feedback input for instructors.

ABOUT THE AUTHORS

Christopher Roos obtained his MSc in Applied Cognitive Psychology at the University of Leiden in 2009. He has since worked as a Human Factors and Training specialist for the National Aerospace Laboratory (NLR), where he performs research on improving the operator performance of Remotely Piloted Aircraft Systems (RPAS) operators and helicopter crews. He holds a pragmatic approach to increasing operational effectiveness and safety; combining innovations in HMI, training, simulation and serious gaming.

Jelke van der Pal is Senior Scientist at the Dutch National Aerospace Laboratory NLR. He has earned a Ph.D. in 1995 from the University of Twente in the Netherlands) on the effectiveness of interactive graphics for education in Formal Logic. Since 1996 he is active in the aviation training R&D, which includes training analysis for the proposed pan-European military pilot school (Eurotraining), and for NATO-level networked simulator mission training. Jelke has coordinated the European ADAPT-IT project, producing a instructional design tool that provides competency-based support for several phases of the ISD cycle and has been responsible for the training concepts in other EU projects, for example the CRISIS project aiming to enhance crisis management training for airports using gaming technology. Currently, he is investigating the principles behind effective simulation and gaming for learning processes and how to determine effectiveness.

Lt. Col. Michel de Rivecourt has a background as a qualified flight instructor and weapons instructor on the F-16 Fighting Falcon in the Royal Netherlands Air Force (RNLAF). After his operational career he obtained an MSc in Psychology. Currently, he is the Head of the Aviation and Occupational Psychology Department at the RNLAF Center for Man in Aviation. The mission of the Center for Man in Aviation is to improve human performance in aviation.

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INTRODUCTION

Heralded in the early 1980's as a means to address Human Error in civil flight, Crew Resource Management (CRM) has since developed into a comprehensive and universally accepted method that has also been adapted outside of the aviation field. Described as "the effective use of all available resources for flight crew personnel to assure a safe and efficient operation, reducing error, avoiding stress and increasing efficiency" it encompasses a wide range of knowledge, skills and attitudes including communications, situational awareness, problem solving, decision making, and teamwork (RAeS, 1999).

Within the Royal Netherlands Air Force (RNLAF) all air crew members receive training in CRM as part of their initial training. To produce long term changes in Human Factors behavior, reinforcement of the CRM principles that are trained in the initial training is necessary. Without reinforcement, the impact of this initial CRM training decays (Kanki, Helmreich & Anca, 2010). CRM elements are addressed in regular live and simulator training, while a dedicated CRM refresher training is provided every three years to all crew members that rely on the use of CRM to maintain safe operations.

In recurrent training, CRM modules traditionally focus on creating or maintaining awareness of the role of non-technical skills such as decision making in safe operations. While awareness can often be successfully raised in participants, actual change of non–technical behavior remains a challenge, and research on the topic is still inconclusive (O'Connor et. al., 2008; Salas et. al., 2006). This is also reflected in comments from CRM trainees indicating that it is difficult to implement certain theoretical aspects of CRM training in practice. This paper investigates the potential to enhance CRM training by gaming.

Enhancing CRM training

The RNLAF Centre for Man in Aviation (CML), seeks to enhance transfer of training to the work floor using practical assignments in which trainees have the opportunity to apply CRM and receive feedback on their performance during the recurrent training. Practical assignments in a CRM training can consume considerable time and effort while providing relatively few learning moments. Therefore, a solution that provides rich experiences, including team aspects and time pressure, is required to achieve the level of effectiveness.

Figure 1. MilNoTechS Framework: Categories and Elements

CML applies a CRM framework of 4 non-technical skill categories, 13 skill elements, and 42 observable behaviors: the MilNoTechS (see Figure 1). The MilNoTechS Framework is based on the civil variant, NOTECHS (Van

Avermaete. 1998). MilNoTechS was first introduced by the Defense Helicopter Command (DHC) in 2011. The practical assignment should create an environment where as many MilNoTechS elements as possible can be put into practice.

The practical assignment also needs to meet the organizational constraints of the CML to minimize logistical burden and preparation. A practical assignment should take no longer than 1.5 hours, including instructions, familiarization, experiences, and feedback. Furthermore, no additional hardware should be required or personnel to support and maintain the training (hardware). Standard laptops or tablets are acceptable as long as the set up does not require specific expertise. While these practical constraints are drastically limiting possibilities, they are considered to be representative for CRM-training providers.

Serious gaming would appear to be an ideal candidate for practical assignments as it provides rich experiences in a relatively short period of time. Since the 90s, several games or low fidelity simulations have been used for CRM training or CRM studies with promising results (Salas, Burke, Bowers, & Wilson, 2001; Helmreich, Merritt, & Wilhelm 1999; Bowers, Salas, Prince, & Brannick, M.,1992). However, addressing as much as possible CRM related skills as well as meeting very restrictive organizational constraints was not directly the aim of such studies. This study reported in this paper specifically intends to meet these requirements.

Training with a Commercial Off The Shelf Game

Several games were assessed on their potential to meet the training requirements and the constraints set by the Centre of Man in Aviation. Only readily available Commercial Off The Shelf (COTS) games were considered for the selection.

COTS multiplayer serious games, such as VBS, are still too complex for a CRM training provider. On the other hand, commercial entertainment games are designed to work out-of-the-box, can be set up with relative ease and may be usable within the limited time frame of the training day. Furthermore, low purchase cost, maintenance cost, and high compatibility with standard consumer products allow for a highly cost effective training solution. Conversely, commercial games are purely designed for an entertainment goal that may distract from learning objectives.

Despite their potential, only few commercial games (from a wide range of candidates) seem to meet the organizational and usability requirements. Most games still require considerable gaming skills, or time to acquire these skills, which is not acceptable for a short CRM practical assignment.

Figure 2. Impression of CRM Game on Tablet

The commercial entertainment game *'XCOM - Enemy Within'* was ultimately selected for a number of reasons. First, it is a turn-based game for two teams. Teams are allowed a fixed period of analysis and tactical decision making before committing to a game action, ensuring a separation between planning and action processes. This facilitates interactions and communication between team-members. Another reason for choosing the game is that it requires little to no skill in controlling the avatars and playing the game. This ensures that any positive or negative outcome in the game is a result of the chosen tactics and not a lack of gaming skill or prowess. A third reason is that it is a competitive game in a military but non-aviation environment. Competition is a natural drive for the target audience and the use of competition ensures each member's commitment in winning the game (defeating the other team). The military setting adds to the expectation level of the audience, while the zero-fidelity (non-

aviation) tasks and team settings do not interfere with specific work procedures and tasks. Lastly, the game allows for online multiplayer, so teams can be physically separated and form their strategy without the other team listening in.

The game is played on a tablet device (see Figure 2). This serves three purposes. First, it makes it easier for all team members to follow the actions visualized on the tablet. Second, the touch screen interface increases easy-of-use and is inviting for all trainees (opposed to one person holding a mouse). Third, it allows the tablets screen to be recorded for future analysis.

While meeting the practical constraints, it still is unsure whether the solution meets the specific training requirements of the CRM training provider. Analysis of gameplay options revealed that all 42 observable MilNoTechS behaviors have equivalent behavior in XCOM. For example, a behavior associated with skill element Workload Management is 'Uses automation to manage workload'. In XCOM, the equivalent behavior would be 'Uses automation, such as *'overwatch'*, to manage workload'. (during *'overwatch'*, the avatar will respond automatically to the opponent team when in reach). To evaluate this potential of using a commercial game for CRM training for the RNLAF a research study was conducted by the Netherlands Aerospace Laboratory (NLR).

By setting up an experimental training that facilitates CRM experiences for trainees and provides input for instructors to provide feedback, the study aims to support CRM training and answer the question: are commercial games effective means for trainees to experience a large number of rich CRM behaviors within a limited time, while laying limited burdens on available resources?

METHOD

CRM game set up

The CRM training session based on XCOM ('CRM game') follows on a classroom session that addresses the theoretical aspects of CRM and discusses personal experiences. The CRM game session aims to provide a practical environment in which trainees can apply the theoretical aspects that were discussed earlier. This will be achieved in two ways: (1.) Trainees can apply theoretical knowledge to the events generated in the game, and (2.) Instructors have the opportunity to give feedback which gives the trainees practical information about how they can achieve better CRM. The assumption is that this supports the trainees to in 'bridging' the gap between theory and practice, ultimately allowing them to use CRM more successfully in actual operations.

Recurrent training classrooms typically consist of up to 13 trainees. In this study, a total of 10 trainees participated. As every trainee needs to be scheduled off their normal activities, there are never more than two or three participants from the same squadron. Each group of participants will therefore be unique and will likely not have worked together before. The backgrounds of the trainees are also diverse, consisting of pilots/co-pilots from different helicopter platforms such as AH-64D 'Apache' attack helicopter, CH-47D 'Chinook' transport helicopter as well as loadmasters, and Do-228 coast guard pilots. All are multi-crew platforms. Likewise, the participants are diverse in terms of age (M = 34 yrs, SD = 6.58 yrs), CRM experience (M = 10.4 yrs, SD = 6.09 yrs) and with ranks ranging from Sergeant 1st class to Captain (NATO ranks OR6 to OF2).
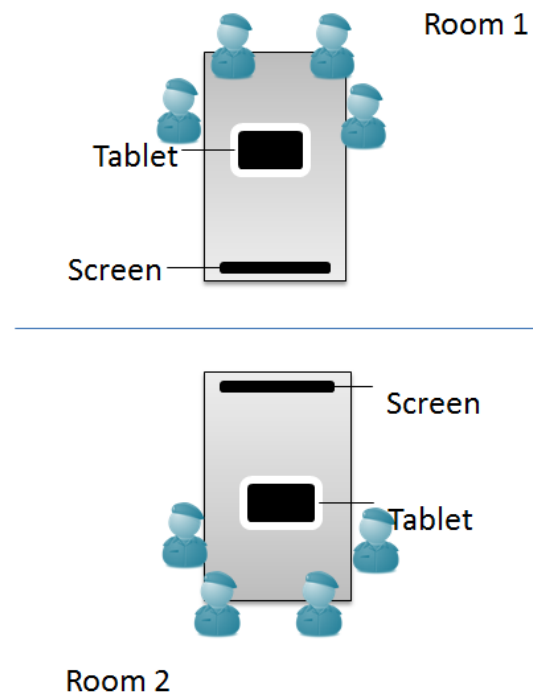
Figure 3. Training Set Up.

The game will be played by two distributed teams, consisting of 4 to 5 players (see Figure 3). The two teams are physically separated so they cannot hear each other as they play the game. Each team shares a single tablet with the game *XCOM - Enemy Within* running on the device. As a tablet screen is relatively small, the screen is duplicated on the laptop screen to provide information for trainees that are cannot look directly on the screen or are sitting at an angle. Each player in the team will also control their own avatar (player) in the game. During the game, both teams take turns making moves. Each turn has a time limit that decreases as the game progresses. During this time, the controlling team will discuss their moves based on the current context, after which the team members position their avatars in the game accordingly The first two rounds serve as an introduction to the game and its controls, as it is very unlikely that any encounters between the two teams will take place during this phase.

During the opposing team's turn, the non-controlling team is able to plan their moves and formulate their strategy. Team members may be given individual responsibilities based on relevant CRM competencies, such as keeping an eye on enemy positions or available resources and health for each avatar. If there are more than 10 students, the non-playing students will be given the assignment to observe the students playing the game. The team that defeats the opposing team wins the game.

During gameplay, the instructor (and possibly observers) will observe the teams and note the identified positive and negative CRM behaviors. Instructor observations are performed on the basis of the previously mentioned MilNoTechS framework for behavioral marking. For research purposes, two additional observers attended the CRM game.

Data collection

During the CRM game training session the activity of the two teams is registered using the internal camera and microphone of the laptop accompanying the tablet on which the game is played. After the training has taken place these recordings are used for a detailed observational analysis using NOLDUS Observer XT software.

The observation analysis uses the example behaviors listed in the MilNoTechS manual to mark relevant CRM behaviors. A total of 42 relevant behaviors, accompanied by behavior examples, are listed in the manual. Some examples of these behaviors are: "Gives personal feedback", "states intentions, goals and boundaries for task completion", and "Identifies future problems". Behaviors in the element 'awareness of aircraft systems' were translated to the game setting ('awareness of game systems'). Each occurrence of these behaviors that is observed in the video recording is marked. After completing the analysis, this produces a clear quantitative representation of the amount and variety of CRM behaviors shown by the trainees during the training with the CRM game.

Background information about the participants is collected using a pre-game questionnaire. After the game session, another questionnaire was distributed to collect information on the participants' experience with the training session and the game in particular.

RESULTS

The behaviors of 10 trainees across the two participating teams were analyzed. The duration of the training material used for the analysis totaled 114 minutes (58 and 56 minutes respectively per team). During this time a total of 731 relevant CRM behaviors were shown according to MilNoTechS standards. This results in an average frequency of 6.41 observed CRM behaviors per minute for the total sample, or 0.6 behaviors per person per minute. All the observed CRM behaviors were sorted into the four MilNoTechS categories coordination, leadership, situation awareness, and decision making as well as the associated thirteen MilNoTechS elements. Figure 4 shows the distribution of observed behaviors across the main categories. Subsequently, Figure 5 shows the distribution of observed behaviors over all thirteen MilNoTechS elements.

A correlational analysis was performed to determine if the participants' prior CRM experience translates in CRM behavior during the training. Results show a significant correlation between these two variables, $r(10) = .65$, $p < .05$.
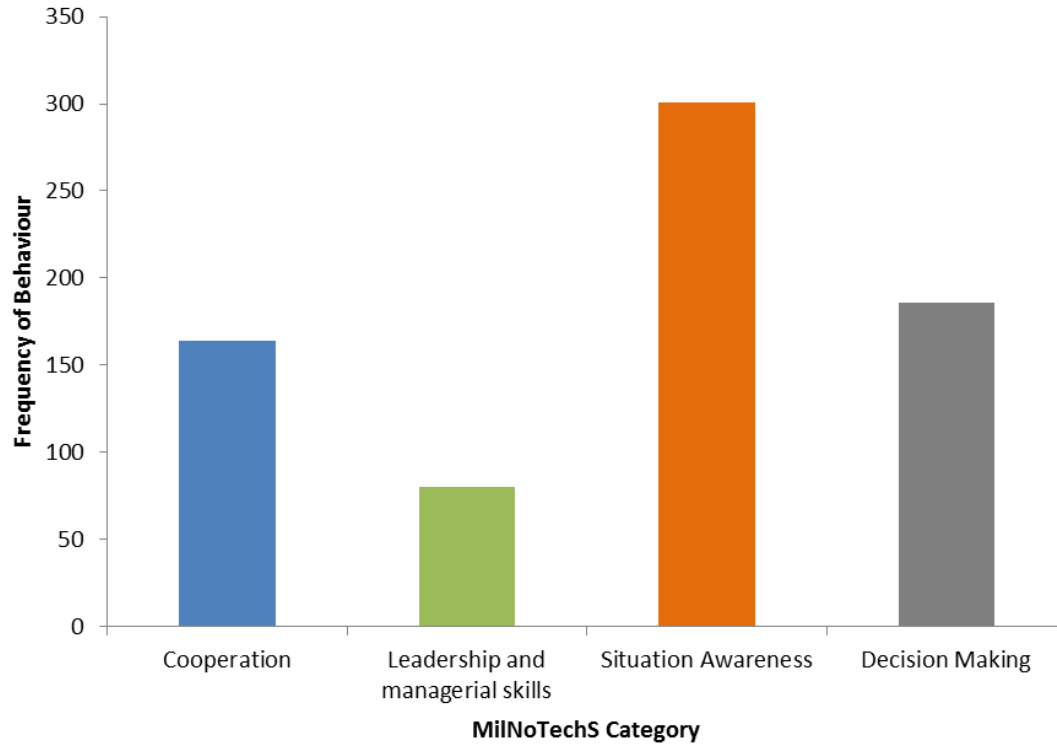
Figure 4. Distribution of Observed CRM Behaviors across the 4 MilNoTechS Categories.
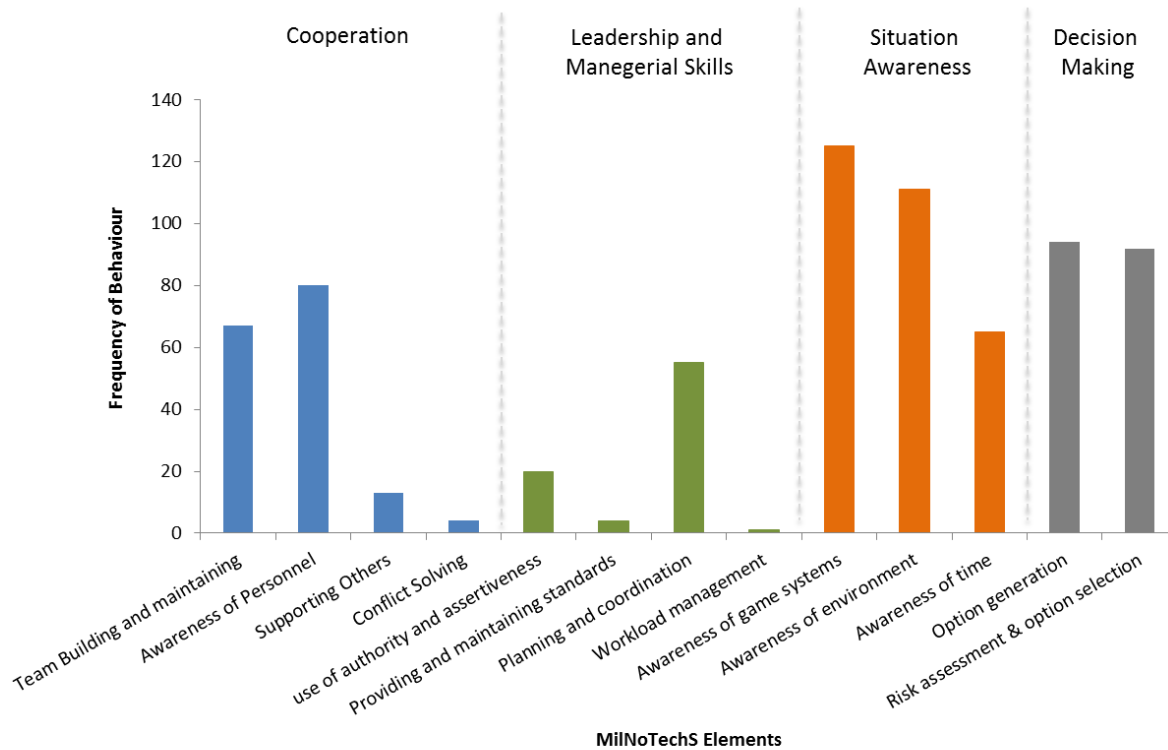

Figure 5. Distribution of Observed CRM Behaviors over all 13 MilNoTechS Elements.

A qualitative evaluation of the use of commercial games in the CRM training was also performed after the training. Overall, participants indicated it was 'useful' to 'very useful' to use the game to apply CRM behavior and receive feedback upon it, rating its usefulness at an average of 4.25 out of 5 (*SD* = .46). Furthermore, participants enjoyed playing the game, rating 'enjoyment' at an average of 4.4 out of 5 (*SD* = .51).

Rating on a scale from 'fully disagree' (1) to 'fully agree' (5), participants indicated that playing the game was most useful for training cooperation (*M* = 4.5, *SD* = 0.52), followed by decision making (*M* = 4.3, *SD* = .67), situational awareness (*M* = 3.5, *SD* = .52) and lastly leadership (*M* = 3.2, *SD* = .63).

Participants indicated they were 'somewhat serious' in applying CRM behaviors during the game, rating it on average 2.25 out of 3 (*SD* = .42).

With regards to the transfer of training from classroom to work floor, participants indicated they expect the transfer of training to 'somewhat benefit' from playing the game, rating it on average 2.22 out of 3 (*SD* = .44).

DISCUSSION

The behavioral marking analysis of the video material produced a very large number of observed CRM behaviors. The high frequency of behaviors indicates the potential of the game to generate experiences and possibly good or bad examples of behavior, with which instructors can thereby provide feedback. However, the extensive post hoc behavioral marking performed for this study is not an option for instructors to use in training practice. Instructors use standardized checklists and experience in observing CRM behavior among trainees. Some behavior can be expected not to be observed by the instructor, while other may be ignored deliberately. The majority of the 731 behaviors marked in the study is not directly positive or negative and do not need to trigger the instructor to provide feedback. Instructors use standardized checklists as well as their experience in observing CRM behavior among trainees. The instructors indicated that an average of three highly relevant CRM behaviors per trainee were observed during the game sessions. This is enough to provide feedback for a normal recurrent training, and to make the CRM game a useful part of the training.

The large amount of behaviors is also likely related to the participants' interest and commitment to the game. Besides indicating that the game is 'very enjoyable', trainees could also be seen to be very committed to the (in game) team's performance and outcome of the game. This is likely the result of a combination of different factors: the competition between the two groups, the user friendly interface, the game design focused on user entertainment and allowing the trainees to control their own in-game characters (avatars).

While 41% of the behaviors relate to Situation Awareness, behaviors from all categories were present during the CRM game training. Trainees indicated that the high time pressure and the unpredictability of the opponent team resulted in a high volume of decision making and dynamic re-planning actions, similar to normal operations. The least amount of behaviors was observed in the elements conflict solving (cooperation), providing and maintaining standards (leadership), and workload management (leadership). This was confirmed in the participants' evaluation of the training, claiming the game was least useful for training leadership. During the training, the groups were left free to determine their own group leader and leadership rules. As this was not enforced and most participants did not know each other beforehand, leadership was not clearly established within the group. Likely this affected the results for this category.

Leadership skills are underrepresented in the results. A different game set up (e.g. assigning leadership role to one of the team members) may stimulate leadership behavior. Also, the average experience level of the trainee group was high. Less experienced teams may require more leadership related behavior.

Besides immediately supporting the recurrent CRM training, the CRM game could potentially also support the transfer of training between the classroom and work floor. To determine the longitudinal aspects of the training, the participants of the training will be approached after a period of three months to determine the effectiveness of the training in relation to the standard training method. The results of this longitudinal research are currently not yet available.

Although the focus of the research was placed on supporting CRM training, it is assumed that the current set up may also work for other training purposes that relate to situational awareness, decision making, leadership and coordination topics. Examples of similar team coordination methods can be found in other domains within the military, and in other high risk fields. As the training solution features a 'zero-fidelity' approach, meaning it takes participants out of their normal routines and provides them with problem that relates to their own task environment only in an abstract way, the current set up using the game *XCOM – Enemy Within* may not work for ground based assault teams, as the setting and tasks will interfere too much with their systems and procedures.

CONCLUSION

The use of a commercial game can be an effective way of acquiring feedback on trainee (CRM) behavior in a limited amount of time and with limited resources, as was demonstrated with the current game. Within a maximum of 1,5 hours to complete instructions, familiarization, experiences, and debriefings, a total of 731 CRM behaviors were observed within the 113 minutes of total observed gameplay. The proposed CRM game solution is suitable in providing CRM instructors with relevant behavior to give feedback on.

Reaction level evaluation of the training indicates that trainees and instructors are positive on the usefulness of the game. They also are positive on transfer of training capability of the CRM game. Whether the game can live up to that expectation will be subject to a further training evaluation study.

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