



Making Decisions in a Virtual Operating Room

Catherine Pons Lelardeux, David Panzoli, Pierre Lagarrigue, Jean Pierre Jessel

► To cite this version:

Catherine Pons Lelardeux, David Panzoli, Pierre Lagarrigue, Jean Pierre Jessel. Making Decisions in a Virtual Operating Room. 17th International Conference on Collaboration Technologies and Systems (CTS 2016), Oct 2016, Orlando, United States. pp.136-142, 10.1109/CTS.2016.0040 . hal-01787391

HAL Id: hal-01787391

<https://hal.science/hal-01787391>

Submitted on 7 May 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Open Archive TOULOUSE Archive Ouverte (OATAO)

OATAO is an open access repository that collects the work of Toulouse researchers and makes it freely available over the web where possible.

This is an author-deposited version published in : <http://oatao.univ-toulouse.fr/>
Eprints ID : 18981

The contribution was presented at CTS 2016 : <http://cts2016.cisedu.info/>

To link to this article URL :

<https://doi.org/10.1109/CTS.2016.0040>

To cite this version : Pons Lelardeux, Catherine and Panzoli, David and Lagarrigue, Pierre and Jessel, Jean-Pierre *Making Decisions in a Virtual Operating Room*. (2016) In: 17th International Conference on Collaboration Technologies and Systems (CTS 2016), 31 October 2016 - 4 November 2016 (Orlando, United States).

Any correspondence concerning this service should be sent to the repository administrator: staff-oatao@listes-diff.inp-toulouse.fr

Making Decisions in a Virtual Operating Room

Catherine Pons Lelardeux^{*§}, David Panzoli^{*§}, Pierre Lagarrigue^{†§} and Jean-Pierre Jessel^{*§}

^{*}IRIT UMR 5505 – University of Toulouse, INU Champollion, France

[†]Institut Clément Ader EA 814, University of Toulouse, INU Champollion France

[§]Serious Game Research Network

Email: firstname.lastname@univ-jfc.fr

Abstract—Immersive Serious Games are collaborative virtual environments where learners are enabled to follow scripted educational activities by interacting in the virtual environment. The joint activity of several users requires the ability to make collective decisions, ideally preceded by an argumentation. During a decision process, opinions are given, arguments are used to back up the opinions, and a decision is made accordingly (or not). One critical feature of a serious game concerns the evaluation of the learners during, or most currently after, the game session. From an educational point of view, this evaluation considers that the argumentation preceding the decision is more important than the decision itself. Yet, the argumentation usually escapes the understanding of the game since the users argue verbally. Channeling the decision making within the boundaries of what a game or a computer system is able to comprehend is an important challenge in immersive learning games. In order to do so, we present the decision feature that we have developed and introduced in a learning game called 3D Virtual Operating Room. Users are enabled to collect information pertaining to the virtual environment. By means of a dedicated activity, users are enabled to make collaborative decisions with as much expressiveness as in real life, that is: expressing their opinion and advancing arguments supporting their opinions; or, should they be convinced by others, changing their mind and withdrawing their arguments. The decision system has been experimented by multiple teams of players and its usefulness has been highlighted by qualitative results. Future work aims to provide further evidence that the collaborative decision system is apt for assessment in a pedagogical context.

Keywords—Collaborative decision making, immersive serious game, virtual environment, communication, voting system.

I. CONTEXT

In healthcare, and especially in hospitals, adverse events can occur anytime during the patient care[1], [2]: wound infections, anesthesia injuries, wrong-site or wrong-side surgery (WSS), wrong-patient, retained surgical items, surgical fires, patient fall, etc. Zegers[3] conducted a study in 21 Dutch hospitals in 2004 whose results showed that surgical adverse events represented 65% of all adverse events. In 1999, Gawande et al.[4] studied 15,000 randomly medical records of patients from Utah and Colorado hospitals. Among the adverse events mentioned in those records, 54% were considered preventable in an industrialized country. Many studies show that human factors are most often listed among the multiple causes of an accident or a near-miss. They also point that the most current root causes of adverse events in the operating room (OR) is due to a communication problem[5], [6], [7].

In the OR, the success of a surgery essentially depends on the dynamic exchanges of information[8], and miscommunication is a prerequisite of most near-misses and adverse

events. Bad or non-suitable decisions most often originate from a wrong representation of the situation, caused by the inability to communicate to decision-making practitioners crucial information regarding the patient and/or the surgery. Yet, training to the management and the prevention of communication-related risks is an arduous and complex task because it implies to control artificially every event and information related to a professional situation. In most cases of an accident, successive failures and/or errors are hardly predictable and skills requested are both individual and collective, and both technical and non-technical.

3D Virtual Operating Room (3DVOR) is a real-time multi-player virtual environment dedicated to train and prevent risk management inside the OR. It is mainly focused on near-misses or usual situations prone to failure, should communication be defective. In this virtual environment, several professionals practicing in the OR (surgeon, anesthetist, nurses) learn to collaborate by means of scripted pedagogical experiences based on real-life professional cases. Each learner plays a different role to compose a virtual medical team. The universe of the virtual OR is composed of the learners avatars, a virtual patient and technical equipment: anesthesia machine, electric generator for the surgical knife, surgical aspiration system, etc. The training offered in 3DVOR addresses the issue of communication with: i) an interactive virtual environment where mistakes can be made freely without other consequences than understanding their impact and learning, ii) an innovative communication system where information can be exchanged and decisions made collectively, and iii) scripted scenarios played by teams of learners and then debriefed in accurate accordance with each team member's actions and decisions.

The virtual environment is designed as a combination of standard game design mechanics and an innovative system of interaction metaphors to reproduce teamwork and team communication. The game and the communication system have been presented and detailed in [9]. It is specifically designed for supporting the training of a team of players and therefore verbal communication between them is forbidden. Communication is channeled within the game environment in such a way that the game engine controls all the information exchanged during the learning session. One shortcoming of the system however, compared to natural conversation, is the inability for the players to exchange false or off-topic information. The virtual collaborative environment aims to represent with great fidelity the structure and the complexity of a socio-technical system as the OR. It allows for controlled manipulations of the decision context and the information exchanged between teammates. The dynamic context also implies that each participant is given the possibility (and the

goal) to update their knowledge of the situation in real-time. 3DVOR also includes documents like the medical record, scanners and/or MRIs, letters, and a safety checklist (actually, the French Surgical Safety checklist, as per the recommendation from the World Healthcare Organization[10] (WHO)). In real-life surgery situations, professionals are expected, before making a decision, to conduct a thorough cross-examination of the available information in order to detect discrepancies and possible sentinel events. The WHO surgical checklist intends to propose a frame of discussion to facilitate and normalize such practices and improve patient safety. 3DVOR, along with the interactive environment and the communication system, embeds a decision-making system which has been designed to support collaborative decisions in the OR. This system, presented to the players as an in-game activity, is detailed in section III.

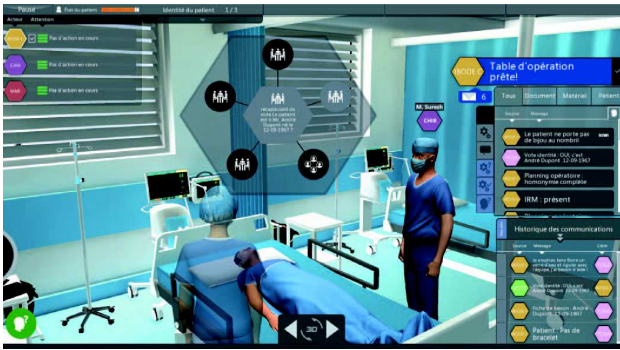


Fig. 1. 3DVOR features a 3-dimensional virtual environment where players can interact with each other's avatars, with the patient or the many props included in the scene (documents, instruments, appliances, etc). Collaboration and communication are enabled by specific user interfaces and an innovative system allowing to manipulate information pertaining to the game. ©3D Virtual Operating Room

II. RELATED WORK

A decision is a choice made among available alternatives. Group decision-making describes the process where a group of people identify the alternatives and collectively choose a course of action. Literature on group decision-making explores two different aspects of the topic: one is understanding the rules that underly the process; another consists in engineering systems for assisting people making optimal decisions.

A. Understanding the process of making a decision

Research dedicated to better understand group decision-making is mainly focused on the role of argumentation[11]. According to the 'Persuasive Argument Theory' introduced by Vinokur[12], the changing views of individuals during a group debate result from argumentation used by the participants. Many experiments showed a strong correlation between the presence of relevant arguments and the changing view in a group. Thus, the role of the argumentation is crucial in a group debate. Reasoning is used to argue and find arguments, evaluate their relevance facing a situation[13]. For Johnson-Laird and Byrne[14], deduction is used "to formulate plans and to evaluate actions; to determine the consequences of assumptions and hypotheses; to interpret and to formulate

instructions, rules, and general principles; to pursue arguments and negotiations; to weigh evidence and to assess data; to decide between competing theories; and to solve problems". Studying the role of reasoning in the decision-making process, particularly organization and rationalization, Simon[15] distinguishes five types of decision:

- The objectively rational decision: the decision is the result of a behavior aiming to maximize values of data in a particular situation.
- The subjectively rational decision : the decision maximizes the chances to reach a given issue according to the real knowledge of the individual.
- The consciously rational decision : the decision is the fruit of the mental process of adaptation between means and purposes.
- The rational decision from the organization point of view: the decision serves the organization's goals.
- The personal rational decision: the decision serves the intention of the individual.

The rational decision-making process is composed of four stages: identify the problem/opportunity, think about alternative issues, evaluate all the alternative and select a solution, implement and evaluate the decision made.

On group decision-making, Laughling et al.[16] propose to order group problem-solving and decision-making tasks on "a continuum anchored by intellectual and judgmental tasks"[17]. Intellectual tasks can be solved by answering a demonstrably correct issue. In that case, the criteria of success is based on the group achievement of the correct answer. Judgmental tasks on the opposite require an evaluative, behavioral or aesthetic judgment, for which there is no correct answer. In that case, the criteria of success is the group achievement of the collective decision. The research exposed in this paper is based on intellectual tasks for which the group has to make decisions facing a problem where the issue can be demonstrated.

B. Decision support systems

Another area of research aims to propose systems for assisting people with decision-making or to train them to make decisions, notably using serious games. Such systems are called Decision Support Systems (DSS). DSS research aims to study and design models representing some of the mechanisms that are implied in the decision making process when a decision-maker is facing a complex situation, either alone or discussing and interacting with other people before making their choice.

Research related to DSS encloses at least two main axes. The first one consists in assisting people making decisions by representing and simulating the different possible alternatives. Artificial intelligence techniques and expert systems have been used to provide smarter support for decision-makers, that include management systems and knowledge-based decision support systems[18], [19]. The second axis consists in designing and developing software, devices or workspaces enabling people to better interact and communicate, thus facilitating their collaboration and leading to better decisions.

Quoting Saaty[20] on decision-making, “To make a decision we need to know the problem, the need and purpose of the decision, the criteria of the decision, their subcriteria, stakeholders and groups affected and the alternative actions to take”. He proposes an analytic approach based on paired comparisons of explicit criteria such as the benefits brought by a decision, or associated risks and costs. Practical methods for assisting the decision-making process originates from the same goal, like SWOT analysis (Strengths, Weaknesses, Opportunities and Threats) which is vastly in use in the business world. In [21], Karacapilidis describes Hermes, a system that augments classical decision making approaches by supporting argumentative discourse among decision makers.

In the education area, teaching decision-making as a skill has resorted to games as early as the 19th century where the *Kriegsspiel* (war game) in Germany was used to teach strategy and decision-making on the battlefield. Lately, video games have accelerated this trend in safety and defense[22], A-CDM (for Airport Collaborative Decision Making)[23], clinical healthcare[24] or business management[25]. Serious games are particularly suited for such an undertaking as they enable a player or a group of players to make decisions freely and experience their consequences in a virtual, safe and controlled environment.

III. DECISION-MAKING IN A VIRTUAL ENVIRONMENT

The system we describe in this article is a schematization of the decision-making process. An example of a decision made in the OR is detailed below: A question is brought up to the other team’s members (could be part of the security protocol like the time-out or before ticking an item on the WHO safety checklist, or raised by a team member to express a concern about something relative to the surgery). The question is debated. Every member of the team is free to express an opinion or none, depending on their knowledge of the situation and in all likelihood on their expertise on the matter. Opinions may be backed up by arguments. Arguments are facts pertaining to the current situation and whose knowledge is held at least by the player using it. Arguments must be collected in the environment prior to be used in a debate. Finally, based on the opinions expressed, a decision is made and acknowledged by all the participants. The system must account for each step in this process.

An important aspect of the process described above is the ability for each participant to build and maintain a personal (as opposed to shared) knowledge of the situation. The communication system in 3DVOR has been designed in such a way that information is given a tangible body in the virtual environment, taking the shape of graphical tags that can be grasped and manipulated using the mouse. Information tags represent facts that are linked to states or values of the virtual environment, like “Patient is anxious” or “Patient’s name on the surgeon letter is Mr. Dupont”. They are collected by each player during the game from the objects or from the patient, or received from other players as part of the player-to-player communication. A colored icon associated with each information tag indicates who is the source of the information. Information tags held by a player are grouped in a panel (as shown at the right in Figure 1) where they can

be accessed anytime, conveniently sorted following several criteria. This panel is called the ‘virtual memory’ of the player since the information listed there accounts for the player’s current and complete knowledge of the environment.

A. Triggering a debate

During a typical game session, each player has a set list of tasks to accomplish as part of the usual activity, which depends on each one’s occupation and work duties. These tasks imply interacting with the environment and, for them to be done right, information ought to be collected beforehand and/or after. Most often, these tasks are achieved individually or in pairs (anesthetist and nurse anesthetist; surgeon and scrub nurse; etc). Yet, on several occasions in a scenario, a problem appears that must be solved collectively. In the game, there are basically two reasons for a collaborative decision to be taken: i) the team or a team member has come across an anomaly upon cross-checking information or upon receiving contradictory information, or ii) the collaborative decision is part of the protocol or good practice, like the “time-out” procedure where every member of the staff must give their go-ahead before the incision is to be made. Either way, in 3DVOR, a collaborative decision is triggered by selecting a topic out of a predefined list of topics available for the scenario. This list is put together during the design stage of the scenario so as to cater for every relevant topic likely to be discussed during the scenario. Non-relevant topics are banned de facto from the scenario.

The collaborative decision procedure is set within a contextual activity called the “voting panel” and overlaying the game window, as illustrated in Figure 2. The window title (① in Figure 2) states the question on which the team is expected to agree on a decision. Questions may take the following wordings: “Assess that patient is Mr. Dupont” (on Figure 2), or “Should the patient be transferred to the operating room?”, etc. Participants to a vote are mentioned as well in the title bar ② by their respective colored icons: anesthetist, surgeon, nurses, etc. One of the participants has a special role of leader ③. The leader is entitled with the final decision and granted the right to ignore the opinions and arguments of others. To each question are associated several answers, which have been predefined as well with respect to the question. Each answer is represented in a separate column by a label and two containers. The upper container ④ displays the icons of the players whose opinion leans towards this answer (see section III-B). The lower and larger container ⑤ receives the arguments in favor of this answer (see section III-C). For instance, on Figure 2, the surgeon and the anesthetist are in favor of confirming the identity of the patient whereas the operating nurse, which is leader on this vote, would like to carry on the identity check. All three have argued their opinion with arguments but, as section IV explains, the outcome is still uncertain.

The vote is time-limited (the time limit has been empirically set to 90 seconds) so as to avoid never-ending discussions between the team members. At the end of the time limit, the leader must pick a choice and make a decision accordingly. It is possible for a vote to include an indecisive answer, like “Continue checking” in the example provided on Figure 2,

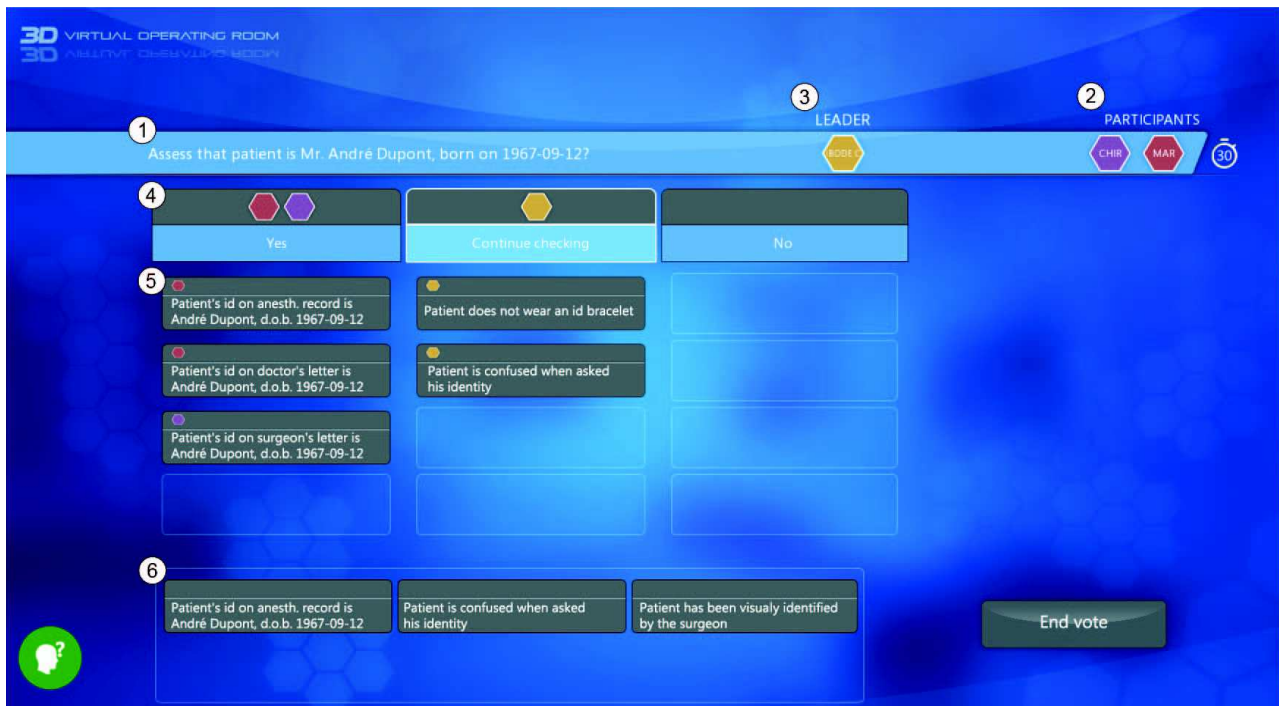


Fig. 2. The voting panel is an in-game activity where learners can express their opinions with the aim of reaching a consensus. Each learner expresses their opinion by clicking on one answer and argues their opinion by placing information on the corresponding areas. Arguments available in the list at the bottom of the screen depend on what information is in their possession at the moment the vote is cast. ©3D Virtual Operating Room

which does not necessarily lead to a firm and irreversible action. Such answers are allowed when designing a question. Yet, to avoid votes to be cast on the same question again and again, indecisive answers are programmed to disappear when the vote is cast for the third time, so as to ensure that a final and productive decision is made eventually.

B. Giving one's opinion

When a vote has been cast by a player, the game pauses for all of them (until the vote is ended) and the voting panel is displayed in real time on every one's screen. Each player first acknowledges the question under debate and starts expressing their opinion. This is achieved very simply by clicking on the desired answer. Immediately, the colored icon representing the player is displayed on top of the text label of the answer. The choice of each player is viewed by the others, as the operation described above is mirrored in real time on every player's screen. An opinion can be changed as long as the time limit has not been reached or the vote closed by the leader. We hypothesize that, depending on the – changing or stable – opinions of the other players, their expertise on the topic and their arguments, a player is likely to be influenced to change his vote just like he would do in a real life similar situation.

C. Arguing one's opinion

In addition to being merely expressed, an opinion can be further supported by arguments placed by players on the corresponding text repositories. Information tags in each player's virtual memory serve as arguments to defend or

argue a point of view. The process of placing an argument consists in dragging and dropping an information tag from an area at the bottom of the screen (⑥ in Figure 2) – where all information held by the player and pertaining to the topic discussed is conveniently gathered – onto the desired repository. This way, the arguments placed on the voting panel are expected to help players influence others, or be influenced by others and change their vote accordingly. The same way he would change his opinion, a player can drop an argument should he realize it is irrelevant or simply misplaced.

On top of supporting opinions, arguments play an important role in the decision process as they help the team to build dynamically a shared representation of the situation and the circumstances under which the decision is put to the vote. In other words, we advocate that the ability for some players to convince others is a question of less importance than how accurate a representation of the situation is likely to be built, and consequently how pertinent the decision.

D. Making the decision

Although the system described in this article aims to facilitate decision-making among several users in a virtual environment, the decision is not actually made by the system. Irrespective of how much the question has been debated, and whether or not the opinions expressed are unanimous or diverging, one person only (the leader) is responsible for making a decision and taking the appropriate action. This is an important aspect of the decision-making, especially in the

operating room, because whoever makes the decision will be liable for its consequences. It is therefore important that a decision will not automatically be imposed by the system on the basis of the opinions expressed, but will be left for the person in charge to take.

In practice, when the vote has ended, as the timer has reached zero, the outcome reflects the opinion of the leader. A new information tag is communicated to all the players with the final decision, and the decision is enforced automatically by the system in the game (“tick the patient’s id checkbox on the checklist”, “transfer the patient”, etc). Whether or not a consensus is found, the only opinion of the leader matters. If the leader has made a decision against the other players, he/she will have to assume the consequences during the debriefing.

IV. EXPERIMENTS

The experiments whose results are presented and discussed in this section were conducted between 2015 and 2016 and served the mere purpose of demonstrating the usability of the decision support system included in 3DVOR. The game scenarios chosen focus on real-life professional situations pedagogically designed to trigger debates on predefined topics at key moments during the virtual surgery: anomaly with the patient’s identity or the surgery site, discrepancy in the patient’s record, and decision to transfer the patient to the OR.

3DVOR was experimented first in 2015 with student nurse anesthetists to check the usability of the communication system and the virtual operating room environment that support the collaborative-decision making system. Then, it was experimented later in 2016 with teams composed of students nurses, student nurse anesthetists and medical interns. The scenarios were improved in 2016 so as to limit the number of times a decision could be postponed. Indeed, we found out during the first experiment[9] that some decisions could be deadlocked by the leader stubbornly and repeatedly picking the option “Continue to check” when the rest of the team disagreed. This disagreement could only be solved by the intervention of the trainer. The improvement of the system consists in disallowing the “Continue to check” option after three unsuccessful trials so that an actual decision, either positive (eg: “Transfer the patient”, “Tick the checklist item”) or negative (eg: “Abort the surgery”), can finally be made.

A. Example of a collaborative decision in the OR

Figure 2 illustrates one of these collaborative decisions, related to assessing the patient’s identity. The identity of the patient must be carefully assessed (and the checklist filled accordingly) before carrying on with the procedure. This calls for a collaborative decision where pieces of information collected from different sources (including the patient himself) must be cross-checked and discussed. In the figure, the opinions of the nurse, the anesthetist and the surgeon are being polled and the current state of the vote can be understood as follows: The surgeon and the anesthetist both agree that the patient is indeed Mr. André Dupont, born on 1967-09-12, and they back up their decision with matching information previously collected on the patient’s record, namely on the anesthetic record, the doctor’s letter and the surgeon’s letter. The operating nurse is however raising a doubt by voting for continuing the assessment, on the

account of 2 arguments. Firstly, the id bracelet, which should nominally identify the patient, is missing. Secondly, the patient is confused and cannot be trusted to identify himself. From this point on, several outcomes are possible. For instance, the surgeon and the anesthetist, alerted by the nurse’s arguments, could change their opinion and rally the opinion of the nurse, or on the opposite stand on their opinion and confront the nurse. The nurse, who has to make the final decision as the leader on the vote, is free to enforce the decision of the majority or his/her own decision, however disputed.

B. Method

For demonstrating the system’s usability, we used a quantitative approach which consisted in identifying patterns within 59 debates recorded during 21 game sessions (2 in 2015 and 19 in 2016). The debate topics were distributed this way: 17 related to the patient’s identity, 7 on the surgery site, 30 on the patient’s transfer and 5 on the patient’s record. During the 21 sessions, every player’s interaction in the game was recorded in a database. This dataset allowed for a meticulous analysis of the different decisions made during the game sessions using the voting procedure.

TABLE I. DEBATE PATTERNS

Start	End	Comment
A	A	All participants agreed with each others throughout the debate.
A	B	The participants agreed at the beginning and disagreed at the end.
B	A	The participants disagreed at the beginning and agreed at the end.
B	B	The participants disagreed throughout the debate.

The method consisted in comparing the opinions expressed by the teammates when the debate starts, ends, and when the decision is finally made by the leader. Let *A* represent a situation of total agreement among all participants (every teammate has the same opinion) and *B* a situation of disagreement, either partial (one participant has a different opinion than the 2 others) or total (every participant has a different opinion), each debate can be associated with a pattern representing the situations at the beginning and at the end of the debate (see Table I). On non-trivial patterns, a finer-grained analysis can be undertaken by looking in detail into the behavior of each participant during the debate (minds changed, arguments placed or withdrawn) and the final decision of the leader. The results are presented in the next paragraphs.

C. Results and discussion

All teams used the decision-making system to debate and express their opinion on a particular subject. The decision-making system is user-friendly enough to be used in a learning context since one game session only did not contain any vote. The data show that on average 2.8 debates have been triggered per session on different topics. This is relatively coherent regarding the part of the WHO safety checklist concerned by the scenarios. The debate related to transferring the patient was more often triggered than the others (30 times against 29 for the three others together). This can be explained by the fact this is a scenario-blocking decision, forbidding the team to advance the narrative further. On the contrary, the other debates can be skipped without practically blocking the surgery procedure, although overlooking those is a threat for the patient’s safety. Looking in detail into the arguments used in the debates related

to patient's transfer, we also found out that many of them were related to anomalies detected in the patient's identity or the surgery site or the patient record documentation. This means that although these debates were less used during the game, the players still felt concerned about checking the potential risks and expressing their doubts to the rest of the team, only they did so in the wrong –or, say, unexpected– place.

TABLE II. DEBATE PATTERNS DISTRIBUTION

Pattern	2015	2016	Percentage
A-A	4	16	33,9%
A-B	1	2	5,1%
B-A	1	9	16,9%
B-B	7	19	44,1%
Total	13	46	

Table II lists and counts the different situations that were faced by the teams of learners, and the vote outcomes. Patterns A-A and B-B are significantly the most frequent. Either all participants agreed throughout the discussion or they did not, neither at the beginning nor at the end of the discussion. The results on the pieces of information used to convince the others and the number of times participants changed their mind help us to understand what are the dynamics inside the negotiation. On average, 5.23 arguments per vote were used and 0.71 were removed from the discussion. On B-B patterns, on average 4.4 arguments were given to support opinions and at least one participant changed their mind during a debate. Therefore, the leader had to make a decision although some of the teammates disagreed.

We focused on B-A and B-B patterns to identify the reasons why teammates would change their mind. From the leader's point of view, typical behaviors were observed regularly throughout the dataset, which were classified in 9 categories detailed in the list below from L1 to L9. The details of each vote was analyzed and distinctive behaviors from the leader were counted and reported on Table III. During a vote, several behaviors can be observed or on the contrary none, which explains why the figures on Table III are inconsistent with the number of votes or the number of sessions.

- L1 Leader rallies the expert's argued opinion
- L2 Leader rallies another participant's opinion who is not an expert
- L3 Leader rallies the expert's opinion who did not argued
- L4 Leader yields the opinion of the majority
- L5 Leader maintains their opinion
- L6 Leader opposes to the expert's opinions who argued with at least a relevant piece of information
- L7 Leader opposes to the expert's opinions who did not argued with a relevant piece of information
- L8 Leader opposes to the opinion of the majority
- L9 Leader do not make a final opinion (time over or 'Continue to check')

TABLE III. LEADER'S BEHAVIORS COUNT (2016 EXPERIMENTS)

Behavior	L1	L2	L3	L4	L5	L6	L7	L8	L9
B-A	5	1	0	2	1	0	0	0	4
B-B	1	1	0	0	14	2	7	3	8
Frequency (%)	21.4	7.1	0	7.1	53.6	25	10.7	3	42.9

Analyzing the 46 cases of discussion of 2016, 28 debates have begun with a disagreement (frequencies on Table III are

calculated on the basis of these 28 debates). We observe that most of the time, the leader has maintained his opinion (53.6%) and/or chosen the answer "Continue to check" when it was available (42.9%). When in contradiction with an expert, the leader has rallied to his opinion when one or several relevant arguments were placed (21.4% of the time) or, decided to maintain his opinion when no arguments was used by the expert (25% of the time). If we consider first the outcome of the debates, we can notice that when the debate has ended with an agreement (pattern B-A, first row on Table III), most of the time either the leader has rallied to the argued opinion of an expert, or the team as a whole has agreed to choose the dismissive answer. When the participants could not reach an agreement (pattern B-B, second row on Table III), it was mainly the fault of the leader deciding not to change his opinion. On several occasions, the leader has even maintained a conflicting opinion with the expert, which can be explained by the absence of any valid argument which could have been used by the expert to influence the leader. These figures tend to confirm that arguments in a debate are decisive criteria for the outcome of a decision-making process.

V. CONCLUSION

In this article, we have presented a system for players immersed in a virtual operating room to make collaborative decisions. The system has not been designed to provide any kind of assistance in the decision making but simply to facilitate the debate and collect enough data for the decisions to be analyzed and debriefed at the end of each game session. The system should therefore be evaluated in terms of how expressive and useful the embedded features are. Preliminary qualitative results indicate a success from this point of view since the system was used many times in every experiment session (except 1) and collected data could actually be used for debriefing the players.

Looking more in detail into the behaviors exhibited in-game by the leader, who is the final decision-making player, has allowed to confirm the role of argumentation in a debate. Relevant arguments placed by experts were able to inflect the decision of the leader whereas the lack of a relevant argumentation was the main cause of a rooted disagreement.

The experiment was set in a virtual OR but we believe our findings could be generalized to other multi-professional workplaces where conflicts can appear and be solved by debating and making collaborative decisions. Future work aims to transpose 3DVOR's decision-making activity into an industry-related context.

ACKNOWLEDGMENTS.

The steering committee of 3DVOR is composed of Pr. P. Lagarrigue, M.D. Ph.D. V. Lubrano, M.D. Ph.D. V. Minville and C. Pons Lelardeux. These works are part of a global national innovative IT program whose partners are KTM Advance company, Novamotion company, the scientific interest group Serious Game Research Network and University Hospital of Toulouse (France). This R&D project is supported by French National Funding: Bpifrance Financement.

REFERENCES

- [1] S. Hempel, M. M. Gibbons, D. Nguyen, A. J. Dawes, I. M. Miakel-Lye, J. M. Beroes, R. Shanman, and P. G. Shekelle, *Prevention of Wrong Site Surgery, Retained Surgical Items, and Surgical Fires: A Systematic Review*, ser. VA Evidence-based Synthesis Program Reports. Washington (DC): Department of Veterans Affairs, 2013.
- [2] S. C. Seiden and P. Barach, "Wrong-side/wrong-site, wrong-procedure, and wrong-patient adverse events: are they preventable?" *Archives of surgery*, vol. 141, no. 9, pp. 931–939, 2006.
- [3] M. Zegers, M. C. de Bruijne, B. de Keizer, H. Merten, P. P. Groenewegen, G. van der Wal, and C. Wagner, "The incidence, root-causes, and outcomes of adverse events in surgical units: implication for potential prevention strategies," *Patient safety in surgery*, vol. 5, no. 1, 2011.
- [4] A. A. Gawande, E. J. Thomas, M. J. Zinner, and T. A. Brennan, "The incidence and nature of surgical adverse events in Colorado and Utah in 1992," *Surgery*, vol. 126, no. 1, pp. 66–75, 1999.
- [5] L. Lingard, S. Espin, S. Whyte, G. Regehr, G. Baker, and R. Reznick, "Communication failure in the operating room : Observational classification of recurrent types and effects," *Quality and safety in healthcare*, vol. 13, no. 5, pp. 330–334, 2004.
- [6] A. L. Halverson, J. T. Casey, J. Andersson, K. Anderson, C. Park, A. Rademaker, and D. Moorman, "Communication failure in the operating room," *Surgery*, vol. 149, no. 3, pp. 305–310, Mar. 2011.
- [7] L. T. Kohn, J. M. Corrigan, and M. S. Donaldson, Eds., *To err is Human: Building a Safer Health System*. Washington, D.C.: National Academies Press, 2000.
- [8] C. L. Plasters, F. J. Seagull, and Y. Xiao, "Coordination challenges in operating-room management: an in-depth field study," in *AMIA Annual Symposium Proceedings.*, 2003.
- [9] C. Pons Lelardeux, D. Panzoli, V. Lubrano, V. Minville, J.-P. Jessel, and P. Lagarrigue, "Communication system and team situation awareness in a multiplayer real-time learning environment: application to a virtual operating room," *Visual Computer*, p. to appear, 2016.
- [10] "WHO Surgical Safety Checklist," 2009.
- [11] B. Brehmer, "Dynamic decision making: Human control of complex systems," *Acta psychologica*, vol. 81, no. 3, pp. 211–241, 1992.
- [12] A. Vinokur, "Review and theoretical analysis of the effects of group processes upon individual and group decisions involving risk," *Psychological Bulletin*, vol. 76, no. 4, p. 231, 1971.
- [13] H. Mercier and D. Sperber, "Intuitive and reflective inferences," in *In Two Minds: Dual Processes And Beyond*, J. Evans and K. Frankish, Eds. Oxford University Press, 2009.
- [14] P. N. Johnson-Laird and R. M. Byrne, *Deduction*. Lawrence Erlbaum Associates, Inc, 1991.
- [15] H. A. Simon, *Administrative behavior*. Cambridge Univ Press, 1965, vol. 4.
- [16] P. R. Laughlin and A. L. Ellis, "Demonstrability and social combination processes on mathematical intellectual tasks," *Journal of Experimental Social Psychology*, vol. 22, no. 3, pp. 177–189, 1986.
- [17] E. Witte and J. Davis, *Understanding Group Behavior: Volume 1: Consensual Action By Small Groups*. Taylor & Francis, 2014. [Online]. Available: <https://books.google.fr/books?id=BQ3sAgAAQBAJ>
- [18] R. H. Bonczek, C. W. Holsapple, and A. B. Whinston, *Foundations of Decision Support Systems*. Academic Press, 1981.
- [19] J. F. Courtney and D. B. Paradise, "Studies in managerial problem formulation systems," *Decision Support Systems*, vol. 9, no. 4, pp. 413–423, 1993.
- [20] T. L. Saaty, "Decision making with the analytic hierarchy process," *International Journal of Services Sciences*, pp. 83–98, 2008.
- [21] N. Karacapilidis and D. Papadias, "Computer supported argumentation and collaborative decision making: the HERMES system," *Information systems*, vol. 26, no. 4, pp. 259–277, 2001.
- [22] A. van der Hulst and M. Ruijsendaal, "Serious gaming for complex decision making," in *1st International Workshop on Pedagogically-Driven Serious Games (PDSG'12)*, Aachen, Germany, 2012, pp. 51–60.
- [23] M. Freese and S. Drees, "D-cite-a serious game to analyze complex decision-making in air traffic management," in *International Conference on Games and Learning Alliance*. Springer, 2015, pp. 23–31.
- [24] J. Kaczmarczyk, R. Davidson, D. Bryden, S. Haselden, and P. Vivekananda-Schmidt, "Learning decision making through serious games," *The clinical teacher*, 2015.
- [25] J. B. Hauge, G. Hoeborn, and J. Bredtmann, "Challenges of serious games for improving students management skills on decision making," *Handbook of research on serious games as educational, business and research tools: development and design*, IGI global, pp. 947–964, 2012.