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Usability of computerized gaming simulation for experiential learning

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Summary: This chapter examines the impacts of computerization of gaming simulations on their usability. Simulation and gaming is an interdisciplinary domain which rallies, among others, the disciplines of education and modelling, and which aim at helping groups of participants to acquire knowledge and skills on complex topics. Gaming simulations can take the form of haptic games or computerized simulations. Yet, the later form may slow down the learning potential for the users. The chapter describes the different types of computerization of gaming simulations. It then examines the effects of computerization, both from the users' perspective (accessibility, captive effect, and flexibility of use) and from the developers' perspective (material, human, and time requirements). Some paths to overcome barriers to experiential learning of computerized gaming simulation are finally presented.

1. Introduction

In the field of simulation and gaming, the problem of software usability has been raised for many years (Jones 1991, Thavikulwat 1991a, 1991b, Myers 1999), perhaps even since the practice of gaming simulation took off in the 1960s (Klabbers 2009a). Simulation and gaming is an interdisciplinary domain which rallies, among others, the disciplines of education and modelling, and which aim at helping people to acquire knowledge and skills on complex subjects in which social dynamics are intertwined with technical and/or environmental problems (Duke 1974, Klabbers 2009b, Crookall 2012). Gaming is the process by which learning takes place. Simulation, on the other hand, is the process used to represent the many interactions, including social interactions, that make up the complex subject being addressed. The range of uses varies widely: city planning, risk management, natural resources management, land use

planning and business management are just a few examples. Gaming simulations, understood as tools or artefacts, are used both in teaching and for decision support (Mayer 2009). In order to illustrate what a gaming simulation can look like, we briefly describe an example of application. LittoSIM is a gaming simulation application used with technicians and decision-makers in coastal cities to help them develop new strategies for coastal flooding risk management (Becu et al. 2017). The simulation artefact can be used to simulate coastal flooding that occurs during storms, the extent and intensity of which depends on the coastal defences and the land use development strategies decided by the players. Players take part in gaming sessions during which they select which coastal defence measures to use (based on various economic, regulatory and operational constraints) and adapt how the land in their fictitious urban areas is used from one year to the next, in an attempt to manage this major risk. Experiential learning is achieved both through the various strategies that the players test using the simulation system and through discussions and exchanges of views between the players on the decisions they need to make (Becu et al. 2019). This example illustrates how simulation and the gaming process intertwine to create experiences for participants that help them to acquire new knowledge, reflect on a particular situation and develop new skills for dealing with that type of situation.

Between the end of the 1950s and the end of the 1960s, the use of simulation and gaming on the one hand and computer simulation on the other developed concurrently as two ways of approaching decision support in complex situations (Meadows 2000). Computer simulation focuses on processing data, finding optimal solutions and comparing various typical scenarios. Simulation and gaming focuses on the lived experience (and in particular the emotional and sensitive dimensions of the lived experience) and on the use of communication and collective intelligence to solve a problem based on each other's opinions and find compromises between everyone's interests (Kriz 2003, Becu et al. 2014b). The question that arises for designers of these tools, who are aiming to use simulation as a way of facilitating experiential learning, is **whether the use of computer simulation within a gaming simulation artefact slows down, or even restricts, the learning potential for the users.** Although computer technology and simulation methods have evolved, this question remains topical for simulation and gaming practitioners, who in practice articulate this dilemma as a choice that needs to be made at the start of the development phase for a new application between developing a computer game or developing an haptic game (haptic in the sense that it does not involve any human-computer interactions).

The first section presents the issue of computerization in the domain of simulation and gaming and the different types of configuration of computerized gaming simulations. The second section explores the effects of computerisation, both from the users' perspective and from the developers' perspective. The

last section presents some recommendations and advances in research to go beyond the limits of usability of computerised applications.

2. Using computers in gaming simulation artefacts

This section first explains the dilemma that arises when deciding whether to use or not computer technology in a simulation and gaming application. Secondly, we examine in more detail the different forms of computerisation used in gaming simulations.

2.1. The computerisation dilemma in simulation and gaming

The study carried out by Crookall et al. (1986) analyses human-computer interactions in several situations that use simulation and in which computer technology is used to a greater or lesser extent. Their results show that, during a gaming session, the computer too frequently monopolises users' attention in use cases where the simulation system is more computerised. This has a detrimental effect on social interaction within the user group and, according to the authors, on experiential learning. This early finding was subsequently corroborated by other work. For example, Paran et al. compare two versions of a game they designed for negotiating the siting of gravel pits: a "paper" (haptic) version and a computerised version (Paran et al. 2010). *"User-friendly, simple and quick to set up, the paper game puts the emphasis on the psychology of negotiation because it insists on interaction and dialogue between the players, bypassing the cumbersome technical aspects. The simplicity of the materials required for this paper version makes it a malleable simulation game that can be easily adapted to the needs and expectations of its organisers. The computerised platform requires more resources but allows the players to manipulate the tools to help the negotiation process. While dialogue is always required, care must nevertheless be taken to ensure that players do not become overwhelmed by the constant stream of information or the technical aspects."* Fedoseev makes the same observation, but he also notes that from the point of view of the game's facilitator¹, a computer-based version is more practical in terms of logistics. A computer is the only gaming equipment required, the tasks involved in completing a round of the game are performed more quickly, and the results and data are provided in digital form, which can be more practical for displaying or analysing them (Fedoseev 2016).

¹ All the gaming simulation applications discussed here, are implemented during workshops where the players are in attendance and where a facilitator organizes and animates the workshop.

The study by (Becu et al. 2014a) compares 29 use cases of gaming simulations. The artefacts were used with different types of local stakeholders involved in companion modelling² processes, either for prospective planning, co-development or consultation purpose. Of these use cases, 21 were workshops involving a role-playing game³ and the remaining eight used computer simulations (in which all the decision-making is handled by computerised agents). The comparison between these two forms of simulation is based on the opinions (positive or negative) of the workshop participants and of the designers and experts who observed the workshops. More than 300 argumentative elements were collected, classified and analysed.



Figure 1: Comparison of games and computer simulations – updated version (Becu et al. 2014a)

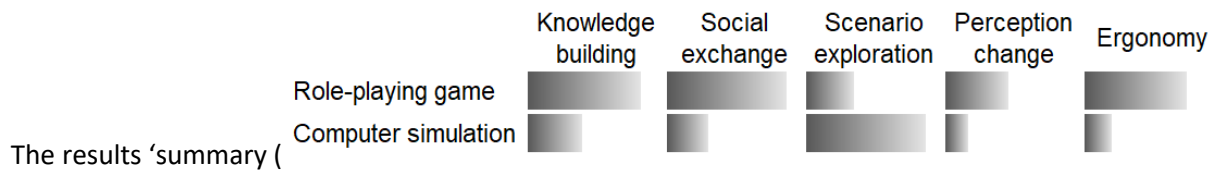


Figure 1) shows that role-playing games are particularly useful in creating a space for discussion and interaction between participants. Their ability to generate learning among participants is also an important factor, as is, to a lesser extent, their ability to trigger changes in perception of the system being studied. Role-playing games appears to be a particularly user-friendly tool that can be adapted to different types of participants. It has a fun aspect, creating a detachment that facilitates interaction and reduces tension, which other tools do not offer. However, some participants do not embrace the playful dimension of the proposed system. Moreover, in the vast majority of cases, simulation of a single scenario lasts two to three hours, which limits the potential to repeat the simulation and explore a variety of scenarios.

Computer simulation, on the other hand, appears to be particularly well suited to exploring scenarios. A large number of simulations can be run over a short period of time, or even repeated several times, allowing participants to explore different scenarios incrementally (Becu et al. 2008, Lidon et al. 2018).

² Companion modeling is a branch of participatory modelling domain, in which simulation and gaming is widely used.

³ The term “role-playing game” is used here in the sense used in the literature on companion modelling. A “role-playing game” simulates a real situation involving human participants; it may or may not use computer-based materials but it involves mainly human to human interactions (Le Page 2017). When computerization is used, it is to represent the decisions of the human players, to record their choices or to display the state of the simulation.

However, it is much less suited to fostering discussion between participants; few changes in perception were noted during the workshops analysed in this study. Their ability to generate learning in the participants is weaker than that of role-playing games, but it still exists. This study thus shows that a computer simulation workshop is rather a space for reflection than a space for social exchange. Lastly, there is a major disadvantage to computer simulation in terms of its poor usability, which can hinder the experience of participants and create a barrier to learning. This is because the computerisation of gaming simulation artefacts tends to reduce their usability and increase their technical sophistication (long waiting times, and difficulty in understanding the content of the tool and in manipulating its interfaces).

2.2. A variety of computerization configurations

Although the previous sections have presented the types of gaming simulations in a somewhat binary way, simply distinguishing between pure computer simulations and non-computer-based games (haptic game, role-playing game,...), in practice there is a whole continuum between computer simulation and haptic games. In the 1960s, Padioleau (1969) presented this continuum and classified gaming simulation applications used in the field of political sociology into three categories: those involving only humans (including games for educational use, strategic games for “decision support” and games for theoretical experimentation (e.g. Schelling 1961)), those involving “mixed simulations” in which (human) participants use computers, and finally “computer simulations”. Two decades later, Crookall et al. (1986) proposed a classification designed to account for human-computer interactions in a computer simulation environment.⁴ This classification distinguishes between two dimensions (Figure 2): whether the human or the computer controls the simulation (control of the simulated events and of the overall progress of the simulation) and which type of interaction prevails (human-to-human interaction or human-to-computer interaction).

⁴ In the Crookall et al. (1986) classification, since it focuses on human-computer interactions, games with no computing component are not considered.

	Player-to-computer interaction prevails	Player-to-player interaction prevails
Players control the simulation	Computer-based simulations (CBS)	Computer-assisted simulations (CAS)
Computer controls the simulation	Computer-dependent simulations (CDS)	Computer-controlled simulations (CCS)

Figure 2: Classification of human-machine interactions in a computer simulation environment (source: Crookall et al. 1986, as cited in Fedoseev 2016)

The four categories in this classification are as follows:

- Computer-Dependent Simulation (CDS) – A pure computer simulation; participants observe the simulation in the same way as a cinema audience.
- Computer-Controlled Simulation (CCS) – The computer controls the simulation, but the players interact with each other to make decisions when the simulation is interrupted.⁵
- Computer-Based Simulation (CBS) – One or more users interact with the computer continuously as the simulation progresses, for example in a flight simulator.
- Computer-Assisted Simulation (CAS) – Users have roles that are an integral part of the simulation; decisions are made away from the computer and the computer is used solely to perform calculations and record decisions.

This classification provides a meaningful way of understanding the main interaction modes that exist at the interface between simulation and “played simulation”. Yet, the ways of interacting with a simulation have evolved since this early classification; technological advances prompt a rethink of the categories proposed by Crookall et al.. In particular, with regard to the CBS category, when it comes to simulations involving several players, today’s technology allows each player to interact individually with a simulation that is shared among several players. In this configuration, human-to-human interactions exist, even though it happens through a computer interface, which usually represents the players in the virtual world by a computer avatar.

Le Page et al. (Le Page et al. 2014) analyzed in more detail these inter-player interactions that take place through the computer. To do this, they attempted to characterise the decision-making agents in simulation and gaming artefacts and the types of decision-making agents. The authors consider that the decision can be made either by a human or by a computer program, and that in a played simulation, a human (or a

⁵ Crookall et al. specify that the CCS category relates to simulations in which a group of people interact with each other either to comment on what is happening or to choose a path for the next sequence of the simulation (as in a “choose your own adventure book” but instead of having an individual reader, a whole group of people choose the continuation of the simulation).

group of humans) can adopt a computer avatar that represents them in the virtual world. They identified four possible types of decision-making agents (from left to right in Figure 3): (i) the human agent, for whom the decision is 100% human and which has no computer avatar; (ii) the composite agent, for whom the decision is also 100% human but who is represented by a non-decision-making avatar in the virtual world; (ii) the hybrid composite agent, for whom some of the decisions are made by a human and some by a computer program (the computer avatar is then partially decision-making); and (iv) the computer agent whose decisions are 100% derived from a computer program.





100% human		intermediate	100% computer
human agent	composite agent	hybrid composite agent	computer agent = virtual agent
			
no avatar	non-decision-making avatar	partially decision-making avatar	autonomous avatar

Figure 3: Types of decision-making agents (Le Page et al. 2014)

To draw a parallel with the previous classification, 100% human composite agent category corresponds to CAS. Conversely, 100% computer agents correspond to CDS, or possibly CCS where the means of control involves something other than the agents. The Le Page et al. classification highlights the range of intermediate configurations that exist between these two end points of the continuum. Within the CBS and CAS categories, there are systems today that include some computer agents and some human or composite agents. In the CBS category, there are also systems that involve only hybrid composite agents. These considerations also relate with ongoing research on hybrid applications, which aims to combine the “space for discussion and social interaction” dimension of games and the “exploratory capabilities” dimension of computer simulations. In this research sector, hybrid game boards for example seek to develop haptic games that use automatic recognition system for in-game actions. Game boards of this kind can be used to design interaction systems between human and computer agents that are much more fluid, or to design new forms of composite agents.

This short literature review shows that the opportunities for interaction between humans through computer technology and digital interfaces have increased significantly, and this raises the question of the link between computer technology and the learning potential of the tool.

3. Effects of computerization in gaming simulations

The first part of this section examines how the degree of computerisation of a gaming simulation affects the user experience, which can lead to inhibiting or promoting experiential learning. Different factors of software usability will be discussed. The second part examines the impact that the use of computers has on the development and deployment of the system. This involves examining the impact that using computer technology has on system designers and simulation workshops' facilitators.

3.1. Weaknesses of computer interfaces' usability for simulation and gaming

The low usability of computerised gaming simulations, as compared to haptic games, has several overlapping causes. These include, the accessibility of the computing environment, captive effect of the computer interfaces and, the flexibility of use of the gaming device.

3.1.1. Accessibility of the computing environment

The computing environment as a medium (screen equipped with a pointing device) is not viewed in the same way by everyone. Some people are more comfortable with computer interfaces than others. For certain groups, this can represent a barrier to the gaming experience. It is important to note that simulation and gaming is practiced with people with a wide variety of backgrounds. For instance, in (Becu et al. 2008), the participants were Hmong people from northern Thailand and they had no experience whatsoever of using computer screens. In another application, in Grand Morin river basin in France (Carré et al. 2014), the participants to a second phase of the project were elderly riverside residents who were not familiar with computers. Similarly, in the LittoSIM game, which involves teams of several people, each with a tablet computer, we observed that often the person most comfortable with computers will take care of the tasks that are performed on the tablet. In this case, players are not penalised in relation to the other teams; however, the distribution of roles within the team is open to question. Gourmelon, who tested different types of simulation artefacts (from board games and the more traditional 2D computer simulation to the latest 3D simulation) with different types of participants (scientists, managers and technicians, locally elected officials and school children), notes varying levels of acceptance (Gourmelon 2017). Both the school children and locally elected officials fully embrace the 3D simulation, whereas the managers consider it simply as a gadget. She also notes that the level of acceptance of 2D computer simulations varies. Scientists and managers accept the 2D game more easily because they are used to working with these tools in their professional life. By contrast, the school children and locally elected

officials find the 2D computer simulation too technical and insufficiently engaging compared to a haptic game.

3.1.2. Captive effect

In the literature of serious game studies, various factors have been identified that help to engage participants and prolong the learning experience: graphic aesthetics and the soundscape; the fluidity of the user experience, allowing the player to lose themselves in the game and forget about the outside world; the narration, which helps to maintain suspense and makes the player want to continue playing; the right level of difficulty and challenge, which maintains the player's concentration and motivation; and the captive effect of the interfaces. This captive effect that a computer interface (whether in a computer game or a digital interface in general) has on its user can be stronger or weaker depending on the person (Frau-Meigs 2011). Researchers in the field attribute this captive effect to two aspects of the computer interface. Firstly, the screen itself *"contributes to drawing our attention towards the screen. [...] It] paradoxically forms a 'boundary frame' that restricts our visual perception [and] in a certain way immobilises our gaze, creating a centring that explains why we feel as if we are absorbed, even hypnotised by the screen"* (Seux 2014). Secondly, the computer interface has the unique characteristic of juxtaposing different types of visual information – *"the screen is a frame (interface) that contains other frames"* (Seux 2014) – and this tends to monopolise our attention: *"It then functions as a capture device: we become absorbed, captivated by light, writings, images [...]"* (Seux 2014). In fact, in a computerised game, where game design calls for both human-machine interactions and social interactions, the computer interface tends to take up too much of the participants' attention to the detriment of direct exchanges between people.

3.1.3. Flexibility of use and free-play

An important aspect of simulation and gaming is the game-play flexibility. The function of flexibility is to make it easier for the player to take a playful attitude (Brougère 1999), in the sense that the gaming system will be able to conform to his choices and freedom of decision, and not force them. Game-play flexibility aim is to guarantee freedom of action, which must not be compromised by problems related to understanding the interfaces or by technical difficulties. Klabbers argues that the free-play dimension is part of the very specificity and morphology of simulation and gaming devices (Klabbers 2009b). Free-play is the idea that users are free to play as they wish. The path of the simulation is never fully scripted in advance and it is impossible to say what the outcome of the simulation will be before it is played. In terms

of game-play flexibility, haptic games have a clear advantage over computer interfaces because of their very nature as tangible objects which can be touched, grasped and manipulated in any desired way. They can be handled with a degree of spontaneity that Duke identifies as an essential element in his definition of gaming/simulation as a mode of communication capable of understanding the “gestalt”⁶ (Duke 1974). In haptic games, there is a degree of flexibility in using tokens and other tangible objects that is not found in computer interfaces (Abrami et al. 2016). The user can pick up the token, touch it, examine it in its entirety, whereas in the computer interface, there is always something hidden, symbolically speaking, that the user cannot touch. To put it another way, in a computer game handling is made through an interface built by someone else, whose logic and meaning may not readily accessible to the user, or may even impose itself to the user (Myers 1999). In addition, the physical pieces of a haptic game can be used more easily as a medium for communication between players. The players may designate a token or a space on the game board to inform other players of a particular situation or signal their intention. It is possible to provide this type of signalling and communication mechanism with a computer interface, as long as the interface is visible to all, for example by using a horizontal projection surface. Similarly, there is immediacy of action with a token, which is not always the case with computers, especially when several calculations are performed after a player’s action. Lastly, the computer interface is developed according to the game mechanics devised by the game designers. If players want to perform an action that has not been coded in advance, they will have difficulty doing it by themselves because that action was not intended. They will first consult the game facilitator or, as the action cannot be performed immediately, will give up attempting that action. Physical game-playing components do not present any such obstacle for players. Players can pick up a game piece and use it for some other purpose or make it do something that was not intended. They can create new game mechanics spontaneously, such as hiding counterfeit money, substituting or adding game pieces, hindering the access of certain players to game resources by physical obstacles – these are all possible ways of hijacking game mechanics that are difficult to reproduce in computerised games.

⁶ Duke defines "gestalt" as a structure or configuration of physical, biological or psychological phenomena so intertwined that it constitutes a functional unit whose properties are not deductible from the sum of its parts (Duke 1974). The concept of "gestalt" shares properties with the modern concept of a complex system, with the difference that it fully integrates the "human factor" in its definition of the functional unit.

3.2. Impact on application development and deployment

When the development of a new gaming simulation application begins, a recurring question arises, which the choice between a non-computerised and a computerised game (CAS, CBS or other types of hybrid configurations). To make this choice, the developers will consider the usability factors mentioned earlier, discuss them according to the target audience, and these are weighed up against the required computing capacity. But these are not the only aspects that need to be considered when choosing one type of gaming device over another. Using computer technology also has an impact on development needs, and on the organisation of the gaming workshops. This section examines how easy and difficult it is to develop and deploy (set up and or organized gaming sessions) in relation to their degree of computerisation. The impact of the use of computer technology is examined from three angles: the material and equipment requirements for organising a workshop, the human requirements during the development stage and during the implementation of a workshop, and the impact on development time and workshop time. Before discussing the case of a computerised system, the following paragraph briefly presents the case of a haptic game from these three angles.

Non-computerised games require little in the way of technical equipment. They use game boards, game pieces, cards or other game-playing components. Although the equipment is not technical in nature, some games may involve a large number of components. Non-computerised games generally require significant human resources during their implementation (facilitators, assistants, observers, etc.). Very few games can be played by just one person; where they can, the facilitator is under considerable pressure. Preparing for a game session can either be quick (10 minutes) or require a much longer set-up time (1 hour or even 1.5 hours), depending on the game-playing components required (boards, game pieces, cards, etc.) and how the play area needs to be configured (arrangement of tables and chairs and separation of areas). A game, excluding debriefing, can last from approximately 40 minutes for the fastest games to several hours for slower games (2 hours on average).⁷

3.2.1. Impact on the material requirements for organising workshops

The computerisation of gaming systems has a significant impact on the technical and computer equipment required to organise a workshop. Some systems require equipment that cannot be transported; in these

⁷ A workshop's duration (which includes briefing, game/simulation and debriefing) can also vary greatly. Some can be quite short (about 1.5 hours), others last half a day, a day or even several days, particularly when the workshop includes several games and several debriefings.

cases, face-to-face game sessions are held in a dedicated room. This is the case, for example, for games that use specially designed interactive tables. This transport constraint does not apply to online computerised gaming simulation which we do not discuss further in this chapter.

When the game is played face-to-face, the computer tools and equipment are such that all the required gaming kit can now be transported in a wheeled suitcase. For example, the LittoSIM game kit comprises several computer terminals, a video projector and a computer server, all of which can be used to organise game sessions involving several teams, each with a dedicated computer terminal and different projection areas (Becu et al. 2017). The downside is the installation time (positioning and connecting the equipment and starting the software applications), which takes longer the more computer hardware there is. However, although the installation time can be significant, setting up the simulation is in principle fairly straightforward compared with a non-computerised game. Setting up the non-computerised simulation involves positioning the board and arranging all the game-playing components before the game can begin. For example, the Maritime Spatial Planning board game (Keijser et al. 2018), setting up all the materials takes a good hour.

3.2.2. Impact on human requirements

In terms of human resources, the development of computerising gaming systems requires computer skills in addition to the game design skills required for any type of gaming system. Modelling platforms adapted to gaming simulation development offer dedicated interfaces to simplify the development process. Nevertheless, game designers must know how to use the platform. The benchmark platform for agent-based modelling dedicated to gaming simulation is Cormas (Le Page et al. 2012, Bommel et al. 2015).

In addition to the needs at the development stage, computer-assisted games may also need a computer operator to be present during the gaming session itself. If the interface usability and the game design allow, entering data into the computer during the game can be carried out by a facilitator dedicated to this task. For example, in the Djolibois game, a “registration office” is situated at each end of the play area, with one computer and one operator (a person from the organizing team) at each “registration office”. The player informs the operator of their decisions, the quantities of wood cut at the “forest office” and the quantities of wood sold at the “town office”. The operator enters the data into the computer model and informs the player of the results before moving on to the next player (Gazull et al. 2010).

3.2.3. Impact on development time and game time

Computerised systems usually require more development time than their non-computerised counterparts. Yet, the amount of time required varies considerably and the development of computerised gaming simulation can range from just a few weeks to more than a year.

Regarding the game time, computerisation reduces drastically the simulation time, particularly for performing calculations and data update. In many cases, the processing carried out by the computer during the calculation phases would be impossible without computerisation. Although the calculations and updates are faster, this does not necessarily mean that the games played with computerised systems are any shorter. There are computerised gaming systems where games last just as long as those of non-computerised systems (2 to 3 hours on average). There are also gaming systems whose games are very fast. This is particularly the case in configurations where several rounds of the same game are played during the same workshop. Each round simulates a scenario: the first round allows players to familiarise themselves with the game, while subsequent rounds may be played faster (sometimes they may last no more than 20 minutes) and allow to test several contrasted scenarios (Becu et al. 2015).

4. Paths to overcome barriers to experiential learning

The previous sections have provided a better understanding of how the computer environment affects the gaming experience and can be a barrier to experiential learning. In this section, we present points of attention and some ideas to overcome these barriers.

First, it is important to take into account the type of public targeted and the level of accessibility required for this public. Depending on the target audience, the development of a gaming simulation can aim either for a computerized or a haptic version. The other important factor to take into account is the degree of free-play that is expected in the game. This depends on the objective of use of the gaming simulation. If a high degree of flexibility is to be achieved, it is advisable to develop a haptic version. However, the accessibility and flexibility of a computerised application can be improved, in particular by playing on its ergonomics. This will be further developed in the following of this section. The last part of this section will present some of the advantages of computerised devices, which can be reached when the constraints linked to computerization have been lifted.

4.1. Avoiding excessive technological sophistication and recent advances

The examination of the issues surrounding the usability of computer interfaces has served to highlight the obstacles it can pose to the forms of interaction and communication that are an integral part of the gaming experience (Duke 1974, Brougère 1999). For the configuration of computerised games (computer-assisted games, computer-based games or other types of hybrid configurations), it is therefore essential to avoid excessive technical sophistication and to focus on the usability of the interfaces, paying particular attention to processing time, the clarity of the interfaces and their controllability (Jones 1991, Becu et al. 2017).

The developers of the Cormas simulation computer program, the benchmark multi-agent platform for participatory modelling and simulation, have paid close attention to this question of usability and flexibility of use of the game-playing components and the controllability of the game mechanics (Bommel et al. 2018b). In the past years, they have integrated relatively user-friendly tools for moving and manipulating virtual game pieces into the platform (Bommel et al. 2015). With several other practitioners, they are now interested in designing hybrid boardgames that would allow players to physically manipulate the game pieces, but calculating the effect of their actions would be computer-based. Such a hybrid boardgame would be a great step forward in overcoming the problems of accessibility and captive effect described above.

Concerning the improvement of the free-play capabilities of computerized gaming simulation, the Cormas developers seek to enhance the control that players can have on the definition of game mechanics. The question, from a modelling point of view, boils down to achieving *“a tighter coupling between the conceptual model and the simulation model by using tools to manipulate both internally”* (Le Page 2017). Two avenues are explored to this end. Firstly, Bommel integrated tools into the platform that can be used during the game to modify (fairly easily and quickly) the computing specification of the interaction mechanisms (Pierre Bommel , Francisco Dieguez , Danilo Bartaburu , Emilio Duarte , Esteban Montes , Marcelo Pereira Machín , Jorge Corral et al. 2014). A game facilitator can use these tools fairly easily, but players find it more difficult to use them. Secondly, Christophe Le Page explored the process of gradually creating specifications for the interaction mechanisms with the participants over the course of a simulation (Le Page et al. 2015).

4.2. Taking advantage of computing capabilities

When the constraints linked to their use have been lifted, the features of computerised games can be useful tools, both to encourage participants to reflect on how the system represented functions and to explore potential future scenarios. Compared with non-computerised games, computerised games have four major advantages. First, the use of computer technology means that important and useful calculations can be performed during the game to report on complex physical phenomena or to simulate automatic game actions, for example. Second, this computing capability can also be used at the end of the game to explore different development trajectories, as in the game FisHcope (Berry et al. 2019). Third, computer interfaces can be used to represent a large amount of information, especially in different forms, which is particularly useful when it comes to integrate asymmetric information and points of view, distributed among the different players (Becu et al. 2014b). Lastly, computers reduce the time required to reset the simulation environment between two rounds of the game, because this is done automatically. With a board and game pieces, resetting is done manually and can take several minutes (Bommel et al. 2018a). In some cases, this reduces the number of facilitators needed to run the game. This is the case, for example, with the games Motte-Piquet and Djolibois (Gazull et al. 2010, Gourmelon et al. 2011), which require only one facilitator thanks to their user-friendly computer interface for entering players' actions. The initial versions of these games, however, required three or more facilitators.

5. Conclusion

This chapter on the usability of computerized gaming simulations has provided a better understanding of how the computer environment can be a barrier to experiential learning and how these barriers can be overcome. The accessibility and flexibility of use of computer interfaces are two key aspects that need particular attention for usability of computerised applications. The use of computer technology also has an impact on the teams developing and deploying the systems. The choice between designing a haptic system or a computerised system therefore depends on the resources available, the calculation requirements, the display requirements and more specifically the asymmetrical display requirements, and the degree of free-play that needs to be integrated into the system.

The criteria for making this choice will most certainly change as technology develops and as the boundary between these two types of system becomes blurred. The current developments in hybrid boardgames, which mix physical manipulation and digital display, have already been mentioned above. Other innovative forms of human-machine interaction are also beginning to be used in simulation and gaming, including the

ability to interact with several people using the same simulation through different individual devices such as tablets or smartphones, or the ability to interact as a group through an interactive table (Marty et al. 2016). The development of these new forms of interaction will certainly shake up perceptions of the role that computing plays in gaming simulations.

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