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Virtual Training, Human-Computer & Software Interactions, and Social-Based Embodiness

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Abstract**—**For professions of high risk industries, simulation training has always been thought in terms of high degree of fidelity regarding the real operational situation. Due to the recent progress, this way of training is changing, modifying the human-computer and software interactions: the interactions between trainees during simulation training session tend to become virtual, transforming the social-based embodiness (the way subjects integrate social skills for interpersonal relationship with co-workers). On the basis of the analysis of eight different profession trainings, a categorization of interactions has help to produce an analytical tool, the social interactions table. This tool may be very valuable to point out the changes of social interactions when the training sessions are skipping from a high fidelity simulator to a virtual simulator. In this case, it helps the designers of professional training to analyze and to assess the consequences of the potential lack the social-based embodiness.

Keywords**—**Interface, interaction, simulator, virtual training.

I. Introduction

WITH the fast progress done in computer engineering the past decades, calculation codes and graphic software have enhanced the possibilities of virtual simulation. This has a major impact on training for professions of high risk industries, such as aircraft pilots, nuclear reactor pilots, or surgeons for example. For these professions, since more than twenty years (perhaps should we write: since the beginning of the conception of training on simulator), simulation training has always been thought in terms of high degree of fidelity regarding the real operational situation. The belief of the necessity to reach the higher level of fidelity in order to guaranty a high pedagogical performance has been so broadly shared and is so strong that studies were done mainly to reduce the distance between the simulated situation and the real operating one. That means everything has been done to increase the degree of contextualization. This was done both from a figurative standpoint centered on the real operating situation, and from an operative standpoint centered on the work activity [1].

For example, Air France company [2] trains and qualifies aircraft pilots on high fidelity simulators (also called full scope or full flight or full scale simulators), a cockpit replication (Fig. 1 and 2) mounted on jacks, reproducing sensorial illusions of acceleration, deceleration, and turning (but not looping!). These high fidelity simulators are expected to give the trainees a high level of contextualization of the simulated situation, it means a simulated situation as much close to the real operating situation as possible so that the trainees may feel the real operational context on simulator. When qualified on simulators, the pilots must take qualification tests on real flights, and when this is achieved, they co-pilot for several years with more experienced pilots, the captains, before becoming themselves captains.

Fig. 1 Example exterior of a Full Flight Simulator of Air France-KLM, Vilgenis training center (Massy-Palaiseau, France)

Fig. 2 Example interior of a Full Flight Simulator of Air France-KLM, Vilgenis training center (Massy-Palaiseau, France)

The aforementioned progress may change this way of training as it is already thought for nuclear reactor pilots: full

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scale simulators reproducing the reactor control room remain full scale simulators with a major difference: every detail of the control room is virtual, designed on an on-touch screen. All boards and panels are thus flat. The pilot does not press a button but touch it, does not turn a button but skip it.

Doing so, something is disappearing from the training: the embodiness. "Embodiness", as introduced by Fauquet-Alekhine in 2011 [3], designates the way workers feel their engine, theirs tools, the facilities… it is a relationship with the equipment, a physical exchange with the work environment. Embodiness is incorporation into the body. This word is preferred to "Incorporation" because it contains the root "body" and preferred to "Embodiment" which is the representation or expression of something in a tangible or visible form (Oxford dictionary). The former is the incorporation inside the subject while the latter is the expression of the inside.

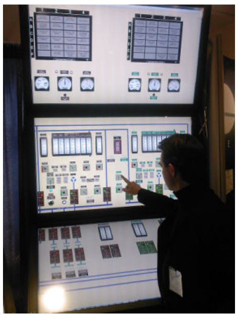

Fig. 3 Full scale simulator for French nuclear reactor pilots (France)

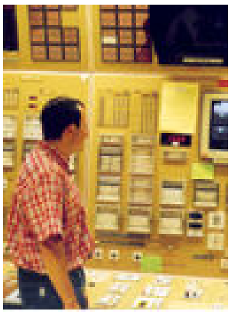

Fig. 4 Hybrid simulator developed by GSE Systems for nuclear reactor control rooms: the three boards are scale 1 on-touch screens and all components are virtual

What becomes then embodiness when all is virtual, when trainees do not have any more this relationship with equipment that helps them to feel the industrial process? A part of the answer is to design the professional training with embodiness elsewhere than on the virtual simulator. Yet, to know how to integrate embodiness elsewhere, it means in another part of the global professional training, training designers must know why, how and what they lose through embodiness and what changes they create for trainees whilst training on virtual simulators instead of full scale high fidelity simulators. While this question is crucial, very few studies are available about it (see the recent study [3]), perhaps because either the question is not thought or because it is dealt case by case: solutions might be so specific that, if they may be included within a theoretical global approach, they cannot integrate a technical global solution.

The same kind of question rises about social interactions: while the previous one could be seen as an object-based embodiness, social interactions raise the question of social-based embodiness. We may easily assume that a subject does not act the same manner in front of a human being and in front of an avatar. Similarly, we can assume that a subject does not interact the same than in current life when acting through an avatar. Thus the problem is slightly the same than for the object-based embodiness: What becomes embodiness when social interactions are full or part virtual, when trainees do not have any more the direct relationship with other actors of the situation that contributes to elaborate the social process?

This paper aims at giving highlights regarding the changes of social-based embodiness during interactions through training simulators, computers and software while the training context skips from high fidelity simulators to virtual simulators.

II. Method

The method was composed of three steps. In the first step, observations and interviews of subjects involved in training situations have been carried out for 8 different kinds of professions trained on computer or on simulator: nuclear reactor pilot, metallurgical industries operator, aircraft pilot, flight fighter, merchant navy captain, harbor pilot, anesthetist, and surgeon. Observations mainly aimed at identifying the social inter-relationships in which the trainee/s was/were involved.

The second step intended to draw a categorization of the possible configurations involving trainees in different social interactions depending on simulation contexts, each with distinctive computer interactions. Yet, as pointed out in a previous work [3], trainees interact nowadays with the computer but not just with the computer, also with the software. In some cases, the hardware may not look like a computer but rather like a mobile phone, and the software may involve a mediator called "avatar". Speaking in terms of Human-Computer Interaction (HCI), but also in terms of Human-Sofware Interaction (HSI) becomes inevitable. The research community has therefore introduced the concept of Computer Mediated Communication (CMC) which is implicated in both HCI and HSI. To draw a categorization of the possible configurations, observations of the first step were used.

The third step analyzed categories of step two in the light of theories of Intersubjectivity with the help of testimonies gathered in the first step, and pointed out strength and weakness of each within a comparative approach. In other words, this step identified how social-based embodiness changes when switching from full scale high fidelity simulator to virtual simulator and vice-versa. This third step is developed in the discussion section.

III. Results

A. Observations of Simulation Training Sessions

Observations and interviews of subjects involved in training situations have been done for 8 different kinds of professions.

The French **nuclear reactor pilots** were trained on full scale high fidelity simulator. The simulator was the replication of a control room. Whilst trained, they could be alone in the control room or up to 6 persons. They interacted together or with the trainers. Trainers sometimes played the role of maintenance workers. Another context of training session was observed while coupling two full scale simulators: this of the pilots, and the one of the field workers.

The **metallurgical industry operators** in an international company in France have been observed during training with a metalworking-rolling, a metal forming process during which metal is passed through a pair of rolls. The control room of the industrial process was simulated by the mean of several computers. Whilst trained, workers could be alone in the control room or up to 3 persons. They interacted together or with the trainers sometimes playing the role of maintenance workers.

The **aircraft pilots** of a French company were trained on full scale high fidelity simulator. The simulator was the replication of a cockpit. They were trained in pair. They interacted together or with the trainer sometimes playing the role of another captain in another plane or the role of an Air Traffic Controller. During the interviews, pilots explained that there could be (rarely) jointed training sessions with Air Traffic Controllers (ATC) by coupling the simulation sessions of two teams each on their respective simulator.

The French **flight fighters** were trained on full scale high fidelity simulator. The simulator was the replication of a cockpit. Whilst trained, they were alone. They interacted with the trainer sometimes playing the role of another flight fighter in another plane, or the role of the head quarter, or the role of an ATC.

The French **merchant navy captains** were observed on a full scale simulator, replication of a ship's navigation bridge. Whilst trained, they could be up to 3 persons. They interacted together or with the trainers sometimes playing the role of maintenance workers or other possible interlocutors from other vessels or harbors.

The French **harbor pilots** were observed on a full scale simulator, replication of a ship's navigation bridge. Whilst trained, they were 2 persons including the captain. They interacted together or with the trainers sometimes playing the role of possible interlocutors from other vessels or harbors.

French **anesthetists** were observed in real operating theatre with full equipment. The simulator was a plastic lifelike mannequin controlled by a computer and simulating the patient (chest anatomically shaped and moved with breathing, heart rate, voice, drugs injection possible). Whilst trained, they were 2 to 3 persons. They interacted together or with the trainers playing the role of nurses, surgeons or other specialized physicians.

French **surgeons** were observed trained on robotic systems such as those developed by Intuitive Surgery (web site: www.intuitivesurgical.com) in the field of mini-invasive surgery. Two cases were considered. One case concerned only one surgeon trained on virtual patient (high resolution graphic software visualizing the patient's inside and simulating actions and consequences of surgical acts), and the other case concerned a nurse and a surgeon working together on high fidelity simulator in a replicated operating theatre where the patient was simulated by an anesthetized pig. They interacted together or with the trainer giving advice.

In addition, a French **firefighter** (also trainer) has been interviewed regarding the training virtual platform (presented in [4]). It provides a virtual reality based environment in which firefighters have their own avatar, can walk, drive or fly and are able to take actions with direct consequences on the situation. Fig. 5 displays a general view of such a platform.

B. Categorization of Social-Based Embodiness

1. Self-Interaction and Software Creator Interaction

Basically, any use of a computer by a subject (common user or trainee) implies at least and every time two social interactions: one with the subject's Self and one with the creator of the software. Social interaction takes place with the Self because, when using any software, any results are the final product for a great part of what has been done by the subject; it is a reflexive and direct interaction through which the computer and the software are a kind of mirror for the subject. The subject thus interacts with the Self. The second interaction with the creator of the software is indirect: the creator has prepared in the software what must be done as a consequence, a result, a reaction to what the subject does, but the creator is not directly in interaction with the subject even though it is the creator who co-acts with the user: this co-action is the result of pre-programmed sequences or algorithms thought before the subject acts. We hence have to consider in all cases the social interaction between the subject (the user or the trainee), the subject's Self, and the creator.

The interaction subject-creator may be achieved through three different means.

The first case concerns the subject using the software by the mean of a computer or an equivalent training tool such as a simulator. In this case, there is interaction between the subject and the machine (computer or simulator) while the software is bounded in the passive role of a calculator to analyze and perform the actions. This case of HMI may be said HCI according to the arguments developed in Section II.

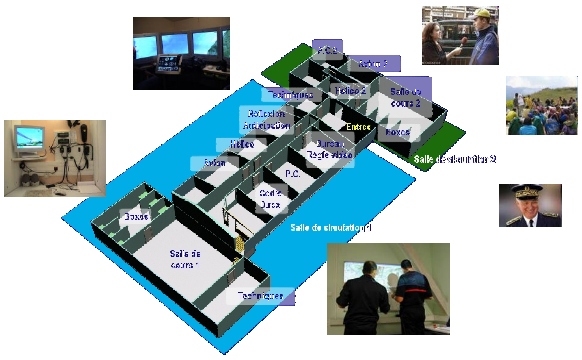

Fig. 5 A firefighting simulation platform

The second case concerns the subject interacting with the software through an embodied agent; if it is not just an embodied agent but an avatar, it concerns the third case. The difference between "embodied agent" and "avatar" has been simply and clearly defined by Bailenson et al. [5]: "Traditionally, researchers have distinguished embodied agents, which are models driven by computer algorithms, from avatars, which are models driven by humans in real time." Therefore, the second case transforms the indirect interaction subject-creator by making this interaction more close to the face-to-face interaction through the interposition of the embodied agent. This embodied agent is nevertheless driven only by the software. Yet the interaction subject-creator tends towards a simulated human interaction with on one hand the real human subject, and on the other hand the simulated human embodied agent representing the software creator.

The third case concerns the subject interacting with the software through an avatar. The avatar is representing the subject inside the software. The avatar may be the only simulated human inside the software or it may interact with one or several embodied agents. In a way, they represent the spirit or the will or the thoughts of the software creator. Here the interaction gains in symmetry because on one hand there is the simulated human through the avatar for the subject, and on the other hand there is the simulated human embodied agent(s) representing the software creator. Subject and creator are facing within the software.

In these second and third cases, the software is interactive (opposed to the passive role of the software of the first case) and the interaction may be said HCI + HSI according to the arguments developed in Section II.

2. Multisubjects Interaction

When a subject is trained at the same time with others (colleagues or co-workers), the aforementioned interactions described in section III-B-1 may be superimposed with interpersonal interactions, subject-to-subject. These interpersonal interactions have basically two forms: direct or indirect.

The subject-to-subject interaction is direct when the trainees are together in the simulator (case of aircraft pilots for example) or around the simulator (case of anaesthetists for example). The interpersonal relationships are of face-to-face type.

The subject-to-subject interaction is indirect when the trainees are communicating and interacting through a mediator which can be of HCI or HSI type.

Regarding the HCI type, the mediator is the simulator. It is illustrated by the aforementioned examples of aircraft pilots trained with ATC or nuclear reactor pilots trained with field workers.

Regarding the HSI type, the mediator is the avatar. It is illustrated by the aforementioned examples of the firefighting simulation platform (Fig. 5). An avatar is representing a subject inside the software. The avatar may be the only simulated human inside the software or it may interact with one or several embodied agents. It may also interact with other avatars if other subjects are trained within the same system.

3. Summarizing the Social Interactions

The different possible types of social interactions for a trained subject on simulator are summarized in Table I which draws what we name the "social interactions table".

The social interactions table draws the features of social interactions for a subject according to the inetracants versus the characteristics of the mediator used to train people together in a simulated situation.

The subject interacts with:

- The Self. The interaction is direct and reflexive. The software has a passive role. All of the observed situations are concerned by this type of interaction.
- The software creator. It may be an indirect HCI interaction: all observed professions are concerned except fire fighter. It may be indirect HSI interaction (case of embodied agent, with or without avatar): fire fighter.
- Other subjects. The interaction is interpersonal. The interaction can be direct (face-to-face): nuclear reactor pilot, metallurgical operator, aircraft pilot, navy captain, harbour pilot, anaesthetist, surgeon. The interaction can be indirect (through a mediator which can be a simulator or an avatar): nuclear reactor pilot + field worker, aircraft pilot + ATC, fire fighter.

TABLE I
SOCIAL INTERACTIONS TABLE FOR A SUBJECT'S TRAINING
DESCRIPTION OF SOCIAL INTERACTIONS DURING A SUBJECT'S TRAINING ACCORDING TO THE INTERACTANT (FIRST COLUMN) VERSUS THE CHARACTERISTICS OF THE MEDIATOR FOR INTERACTING. THE CROSS SHOWS THE ABSENCE OF MATCHING

subject interacts with:	**mediator characteristics:**		
	passive software	**embodied agent**	**avatar**
The Self	direct - reflexive	X	direct - reflexive
The software creator	indirect	indirect	X
Other subjects	direct / indirect interpersonal	X	indirect interpersonal

The mediator characteristics are fundamental as they contribute to shape and pattern the features of the social interactions. Mediator characteristics also determine the degree of contextualization of the simulation situation. The closer the simulated situation is to the real operating situation, and the higher the degree of contextualization is. Hence when the mediator integrates embodied agent or avatar, the degree of contextualization of the simulation situation is decreasing. This implies that a specific work will be necessary after the training session to ensure the transference of the acquired knowledge, know-how and skills regarding social-based embodiness towards the real operating situation.

IV. Discussion

Many studies are now available regarding the specific or general effects of virtual training facilities, the relationship between trainees and software and between subjects through the software [6]-[8], about the effect of avatar [9], [10], the effect on the collective work or leadership [7] or the benefits for specific professions, especially for medical jobs [11]. Recent reviews are available on the subject (see for example [12]). All these studies suggest that virtual simulation have pointed out the broad range of virtual simulators possibilities in which sensorial system can be quickly stimulated by the software, trigger imagination, may lead the trainee to faster improvement not only because of the pedagogical content of the software, but also because of the pleasure it gives to the subject. All these possibilities may occur despite the decontextualization of simulated situations. Even more: decontextualization may be used as a lever of improvement. Professor Mavre, from the Institute of Applied Arts in Paris (France) explained that [13], in this case, decontextualization "is all about putting the learner inside a context in which his professional reflexes will be neutralized, allowing reaching for a deeper level of the brain mechanism of an individual".

All these findings lead or may lead the decision-makers in companies to think about virtual training facilities to replace full scale high fidelity simulators Virtual training facilities are easier to implement and to update than full scale simulators, and thus cheaper.

Yet, before choosing such a professionalization re-orientation, it is important to identify and understand the implications of such a choice from the embodiness standpoint as argued in Section I.

Regarding the social-based embodiness, the social interaction table (presented in Table I) appears to be a useful tool in order to carry out such an analysis. To make the demonstration, let us consider the case of nuclear reactor pilots. We observed that they were trained on full scale high fidelity simulator. The simulator was the replication of a control room. Whilst trained, they could be up to 6 persons in the control room. They interacted together or with the trainers sometimes playing the role of maintenance workers. For these training sessions, there were no embodied agent nor avatar, and the interpersonal interactions were direct. Using the social interaction table, we highlighted how these sessions are concerned on Table II.

Considering now that the training could be done on virtual simulator involving embodied agents and avatars for all trainees, the social interaction table would become as presented in Table III.

Comparing tables II and III, at once the potential zones of problems appear. Every switch from one column to another changes the features of social interactions and lead to another process of social-based embodiness. They are potential zones of problems in that the changes of the nature of the social interactions make trainees elaborating different know-how and skills regarding social interactions. This is not without any consequences: moving to the right hand side of the social interactions table makes the subject farther from the features of social interactions in real operating situations.

Bailenson et al. [5] explained: "Unlike telephone conversations and video-conferences, interactants in virtual environments have the ability to systematically filter the physical appearance and behavioral actions of their avatars in the eyes of their conversational partners, amplifying or suppressing features and nonverbal signals in real time for strategic purposes. These transformations can have a drastic impact on interactants' persuasive and instructional abilities."

On the basis of Goffman's presentation of the Self in everyday life [14], subjects presenting themselves in any social context are involved in a constant performance, adapting appearance, behavior, gestures and acts, even language [15], the aim of which performance is to offer the desired impression of the Self to others.

TABLE II
SOCIAL INTERACTIONS TABLE FOR THE CURRENT TRAINING OF NUCLEAR REACTOR PILOTS

subject interacts with:	**mediator characteristics:**		
	passive software	**embodied agent**	**avatar**
The Self	direct - reflexive	X	direct - reflexive
The software creator	indirect	indirect	X
Other subjects	direct / indirect interpersonal	X	indirect interpersonal

The boxes concerning this case are highlighted

TABLE III
SOCIAL INTERACTIONS TABLE FOR THE POSSIBLE VIRTUAL TRAINING OF NUCLEAR REACTOR PILOTS

subject interacts with:	**mediator characteristics:**		
	passive software	**embodied agent**	**avatar**
The Self	direct - reflexive	X	direct - reflexive
The software creator	indirect	indirect	X
Other subjects	direct / indirect interpersonal	X	indirect interpersonal

The boxes concerning this case are highlighted.

In this context, how may we have confidence in the sincerity of a virtual interlocutor knowing that likely every detail can be adjusted, adapted, rectified in order to comply the aforementioned desired impression of the Self? The nature of a social interaction is obviously transformed by altering informative details related to the presentation of the Self to others.

To illustrate the question, we may refer to Prof. Bailenson and co-workers' experiments. Using the Big Five scores (from the Five Factor Model [16] assessing the human personality over five main socio-psychological factors: Openness, Conscientiousness, Extraversion, Agreeableness, Neuroticism), they compared the expression of subjects' personality in a virtual world with subjects' personality in real life [17]. They showed how in virtual world the personality is expressed differently than in real world, and how it is difficult to correlate virtual behavior of the avatar with personality of the subject.

As a consequence, the question of trustfulness rises in the case of virtual training sessions involving avatars. This question may be interestingly investigated and analyzed in the light of Intersubjectivity theory.

Intersubjectivity, may be understood as One's orientation to the orientation of Other [18]. Yet, intersubjectivity may concern a reflexive orientation: in the line of Mead [19], [20] suggesting that reflection as part of intersubjectivity may be understood through a perspective-taking approach, Ichheiser [21] proposed the analysis of any inter-relation on the basis of three interactional levels: the individual/group self-perception, the individual/group perception of Other, the perception of individual/group of the Other's perception of themselves. According to Gillespie [22], these three levels may be considered to operate at two levels from the interactants' standpoint: "First, there is the level of a person's direct perception of Self or Other, and second there is the level of perception of the perspective of Other" which helps "to conceptualize how someone or a group might try to appear trustworthy. To appear trustworthy they must orient to the criteria that they think Other is using in order to determine trustworthiness". The first level was conceptualized as the "direct perspective" by Laing et al. [23], the second as "meta perspective", and the authors added as a logical possibility a third level, the meta-meta-perspective: the perception of individual/group of the Other's perception of their perception of themselves. On the basis of Laing and co-workers studies, Gillespie [22] reformulated how these three levels of perspectives could be important: referring to the Cold War, the authors argued that "the distrust between East and West operated at each of their three levels. Not only did East and West fear each other (direct perspectives), but they were each aware that the other feared them (meta-perspectives), and they each knew that the other was aware that they knew the other feared them (meta-meta-perspectives)." Gillespie [22] emphasized that a context of trust is satisfied when the three levels are fulfilled in congruence.

In the case of virtual training sessions involving avatars, referring to Bailenson and co-workers studies [5] pointing out that "interactants in virtual environments have the ability to systematically filter the physical appearance and behavioral actions of their avatars in the eyes of their conversational partners", the three levels of intersubjective perspective taking may have low probability to be fulfilled in congruence. Therefore, the question of trustfulness is worth to be investigated.

Furthermore, and consequently to the question of trustfulness, the transference of know-how and skills developed and acquired during virtual training sessions involving avatars may be difficult while such a transference from the training session to the real operating situation is the final pedagogical goal of the training.

V. Conclusion

Our field observations and analysis tried to propose a categorization of the social interactions encountered by professions of high risk industries whilst trained on simulator. We have achieved the design of a tool, the social interactions table, describing the possible social interactions during a subject's training according to the interactant versus the characteristics of the mediator implemented for interaction. This tool appears helpful to characterize simulation training situations and to compare one situation to another. Specifically, this tool may be very valuable to point out the changes of social interactions when the training sessions are skipping from a high fidelity simulator to a virtual simulator. In this case, it helps the designers of professional training to analyze and to assess the consequences of the potential lack the social-based embodiness.

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