An Innovative Immersive Environment to Assess Non-Technical Skills: A Pilot Study

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***Abstract*—Because non-technical skills are more and more important to improve safety in industry, this paper is aiming to present an innovative tool to assess these non-technical skills, by using an immersive environment. Even if all existing assessment methods (e.g., simulated clinical scenarios, objective structured clinical examinations, and questionnaires or written assessments) provide interesting data, they present several limitations (weakness of their theoretical background, only based on subjective and individual data). The main goal of this paper is to present an innovative tool to assess non-technical skills, by using an immersive environment, allowing collection of quantitative and objective data for several individuals engaged in a collaborative and a complex cooperative task. Performances of the team, performances, verbalisation and behaviors of each participant/player are automatically recorded by the immersive system and a debriefing session was realized with all participants/players at the end of each game. Our results obtained with 35 participants tend to confirm that technology such as an immersive environment created by Virtual Rangers can offer a new and positive model for assessing non-technical skills. Finally, advantages of this iterative and incremental human-centered design are discussed in the domain of the assessment of non-technical skills.**

***Index Terms*—virtual reality; human factors; behavioral science; human-computer interaction**

I. Introduction

Many 21st century operations are characterised by teams of workers dealing with significant risks and complex technology, in competitive, commercially-driven environments. Informed managers in such sectors have realised the necessity of understanding the human factors to their operations if they hope to improve production and safety performance. While organisational safety culture is a key determinant of workplace safety, it is also essential to focus on the non-technical skills of the system operators based at the 'sharp end' of the organisation [1].

In this context, a consortium has been created through an industrial chair. The "Behavior" chair held jointly by National Engineering School of Metz (ENIM) and the research unit 2LPN (Lorraine Laboratory of Psychology and Neuroscience of Behavioral Dynamics, UR7489) related to University of Lorraine (France). This Chair promotes collaboration between three main stakeholders: expert researchers in human factors, professionals in industrial field and experts in scripting and development of virtual environments. All of the stakeholders have opted for a training program enriched by an approach human-centered, i.e., centred to their behaviors and psychological factors underlined. The objective of the "Behavior" Chair is to develop innovative pedagogical innovations to train future engineers, professionals in industry, executives and managers in the industrial field or civil security in the behavioral approach to risk management in companies. More specifically, the challenge is to develop and validate tools (through virtual reality simulation) aimed at developing non-technical skills associated with collective tasks in an emergency or risk context. The tools developed by the "Behavior" Chair are used in training courses to assess the technical and non-technical skills mobilized in situation, and to engage the trainees in reflexive processes promoting the development of good practices and the associated skills.

This paper is aiming to present (i) one of the digital tools (i.e., an immersive environment) developed in this "Behavior" Chair oriented to the assessment of non-technical skills and (ii) the results issued from the first pre-validation testing of this digital tool conducted with 35 volunteers. In Section 1, the importance of non-technical skills in workplace safety and the different techniques used to assess them are presented; Section 2 is dedicated to the methodology used in our experiment by describing the characteristics of participants, the immersive environment specifically created, and the protocol and the procedure; In Section 3, the first results obtained in our pre-validation testing conducted with our 35 participants are described by distinguishing quantitative and qualitative data; Finally, in Section 4, perspectives and implications are discussed.

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A. Non-Technical Skills to Improve Workplace Safety

From a historical point of view, non-technical skills emerged from research into aviation accidents which occurred in the late 1970s, such as the Tenerife airport disaster in 1977. As technology improved, the human contribution to accidents had become more apparent. Rather than there being any technical fault with the aircraft, it became clear from subsequent investigations that things, such as poor communication between pilots and air traffic control could be primarily responsible for these crashes. Since these disasters, a lot of other domains focused attention to non-technical skills, particularly in industry [17]. Because the modern complexities of healthcare delivery and rapid expansion of medical knowledge necessitate a high-functioning team approach, which requires human factors engineering and non-technical skills to operate effectively, multiple tools have been developed for the assessment of non-technical skills in healthcare [2] [7] [9]. Failure of non-technical skills has been linked to poor quality and safety of care [3]. For instance, a series of studies found a strong correlation between surgical team situational awareness and fewer technical errors [4] and a 3-year retrospective review of fatal medical accidents submitted to a third-party safety organisation found roughly half to be due to failures of non-technical skills, most often related to situational awareness, teamwork and decision-making [5].

While authors do not agree about the number of non-technical skills (e.g., from 11 for [1] to 22 for [12], a consensus exists about some crucial non-technical skills existing in all domains (Figure 1): time and stress management, situation awareness, communication, adaptability, creativity. In other words and in accordance with [14], we define non-technical skills as ”intra- and inter-personal (socio-emotional) skills, essential for personal development, social participation and workplace success. They include skills, such as communication, ability to work on multidisciplinary teams, adaptability, etc.; these skills should be distinguished from technical, or “hard skills”. We characterized them as “skills” in order to emphasize the fact that they can be learned/developed by suitable training efforts, and they can also be combined, towards the achievement of complex outcomes.

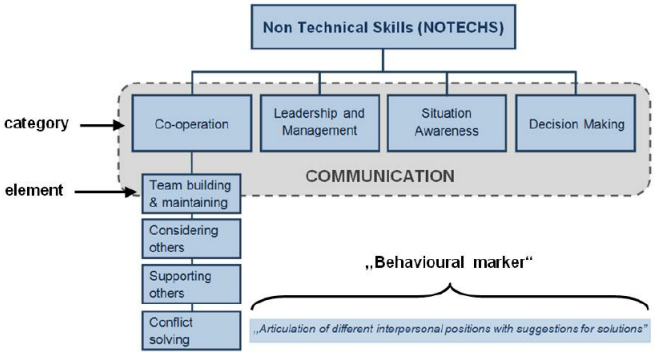

Fig. 1. Non-technical skills according to [5] and [6]

In other words, non-technical skills are defined as the social (teamwork, leadership, communication), cognitive (situation awareness, decision-making, cognitive readiness, task management) and personal management (stress and fatigue management) skills necessary for safe and effective performance. In other words, non-technical skills are the cognitive and social skills required for efficient and safe operations. In some domains such as civil aviation, nuclear power plant, high risk industry, it has long been appreciated that the majority of accidents could have been prevented if better non-technical skills had been demonstrated by personnel operating and maintaining the system. Whatever the domain (healthcare, industry, services, transportation, etc.) and whatever the activity (maintenance, problem solving, monitoring, etc.) when applied well, non-technical skills are invaluable in maintaining system safety and ensuring efficient and effective operations. For example, people often need to work in teams and communicate with one another to get a particular job done. Learned through training and practice, the best operators possess good non-technical skills which enables them to, for example, work well with others, work more safely, have a good ”situation awareness” and communicate more effectively.

B. Assessment of Non-Technical Skills

Assessment methods related to non-technical skills fell into three categories [8]: simulated clinical scenarios, objective structured clinical examinations, and questionnaires or written assessments. Even if all these tools provide interesting data, they present the following limitations:

- Tools to assess non-technical skills were often developed locally, without reference to conceptual frameworks. Consequently, the tools were rarely validated, limiting dissemination and replication.
- Tools to assess non-technical skills are essentially based on qualitative and subjective data issued from verbalization or written data.
- Activity used to assess non-technical skills are often individual and ”simple” activity (i.e., one people is asked to complete one specific task).
- The assessment of soft skill is therefore widely practised, but there is little in the way of research or evidence on how well this assessment is done.

. The main goal of this paper is to present an innovative tool to assess non-technical skills, by using an immersive environment, allowing collection of quantitative and objective data for several individuals engaged in a collaborative and a complex task.

The immersive environment created to assess non-technical skills has been elaborated by taking account of data issued from a large literature review suggesting that non-technical skills standards and assessments should [16]):

- Be aligned with the development of significant, soft skills goals.
- Incorporate adaptability and unpredictability.
- Be largely performance-based.

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- Add value for teaching and learning.
- Make students' thinking visible.
- Valid for purpose.
- Generate information that can be acted upon and provides productive and usable feedback for all intended users.
- Provide productive and usable feedback for all intended users.
- Be part of a comprehensive and well-aligned system of assessments designed to support the improvement of learning at all levels of the educational hierarchy

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II. METHOD

In this section, details are provided about the immersive environment created by Virtual Rangers to assess the non-technical skills, and about the design and procedure of the pilot study. This environment offers a role-playing simulation.

A. The Immersive Environment

The specific immersive environment created by Virtual Rangers to assess non-technical skills has been elaborated in accordance to Boud's ideas [15], having summarised a body of research on assessment, who listed desirable attributes of assessment as including:

- Assessment should be authentic (reliable).
- Assessment should be process rather than results oriented.
- the act of assessment signals the importance of what is being assessed, so assessment is a driver for learning; and assessment activities need to be seen by students as worthwhile and interesting activities.

. The use of immersive environment to assess non-technical skills is recent (e.g., [9] [18] [22]). Traditionally, immersive environments have been used in the development or the assessment of hard skills, particularly in technical areas such as health, engineering, defence or the environment [19] [21]. However, they can also be applied in the assessment and development of soft skills [20], which are increasingly key competencies for an individual in the twenty-first century [11] [12].

Fig. 2. Screenshot of the submarine viewed by each participant.

On the one hand, immersive environment headsets provide an immersion that focuses the user's attention on her/his actions in the virtual environment. On the other hand, the controllers/joysticks allow natural gestures to be reproduced to catch, use or throw objects. Tactile interactions are also simulated to reproduce screen interfaces.

Fig. 3. Screenshot of the desk viewed by one of the players.

B. Participants

For this pre-validation testing session, thirty-five participants/players have been recruited to test the immersive environment specifically created. All are adults, volunteers, native French-speakers, and have no experience with immersive environment or have a very low level of experience with this kind of digital tool.

C. Task and Procedure

The assessment of the non-technical skills performed with our specific immersive environment has several successive steps:

- First, participants/players are asked to take a seat a the specific room to use the immersive environment (Figure 2). The situation/room can accommodate from 2 to 6 players.
- Then, each participant/player is equipped with a VR headset and is asked to take the two associated controllers/joysticks.
- After a training session, participants/players are informed that they will perform a collaborative task in a specific environment (i.e., a submarine; Figure 3). The topic (i.e., the submarine) has been chosen for the following reasons: a priori, no participant has experience in a submarine; to prevent falls, all tasks can be performed while the participant/player is seating down; and no specific technical skills are required to perform the different missions. Randomly, one of the participants/players is designated as a captain.
- To perform the collective task, each participant/player must realize specific tasks (Figure 4). They received instructions that they have to accomplish missions that will require precise synchronization and collaboration to achieve the objective of the module.. To do that, s/he is asked to listen and to understand to the instructions given by the captain, to use displayed information in front of

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her/him, to use her/his hands to perform specific tasks and finally, to communicate with other participants/players.
- All interaction between participants/players are recorded to provide qualitative information about their behaviors, their verbalization and their attitudes.
- In parallel, all performances and all quantitative behaviors (e.g., time spent to perform the task, numbers and types of errors) are automatically recorded by the digital system.
- At the end of the game, a debriefing session is conducted with all participants/players. S/he is invited to comment freely their own behaviors, their difficulties, their limits or misunderstandings, etc. This debriefing session is supervised by an expert in ergonomics or work psychology.

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Fig. 4. Example of a session performed in the Meta Behavior room by 6 participants.

III. Pre-Validation Testing: First results

The immersive environment several full iterations of software development, and after every iteration, the environment was tested in order to gain information about key elements: in particular, those elements that we believe can play the most prominent role in the efficacy, usability and acceptability of the immersive environment as a training and assessment tool. Iterations of development and testing are fundamental for assessing the development phase and make sure that the objectives are met to an acceptable extent. After the several iterations presented here, the immersive environment was released for an extensive validation phase

A. Quantitative Data

Performances of the team, performances, verbalisation and behaviors of each participant/player are automatically recorded by this system. By this way, it is easy to collect quantitative data such as the rate of success/failure, time spent to complete the tasks, the number and the type of each failure, etc. For instance:

- As Figure 5 shows, the more players there are, the greater the number of errors (Person's r = .557, p=.0001).
- As Figure 6 shows, the more players there are, the longer it takes to complete the mission Person's r = .622, p=.0001).
- But, finally, as Figure 7 shows, the number of errors has no significant impact on the success rate (Student't = .543, df=33, p=.591).
- And, in the same way, as Figure 8 shows, there is no significant relationship between the numbers of errors (x-axis) and time spent to complete the mission (Person's r = .361, p=.033).
- Some failures are particularly frequent. For instance, during the game, each participant/player was asked to take the good Personal Protective Equipment (PPE), i.e., a glove worn to minimize exposure to hazards that cause serious workplace injuries and illnesses. Each participant/player must choose the right gloves for the type of hazard (chemical, electrical, ...), this glove can be different among the player. Several participants/players did not choose the correct glove because they did not spend attention about the characteristics of the material.

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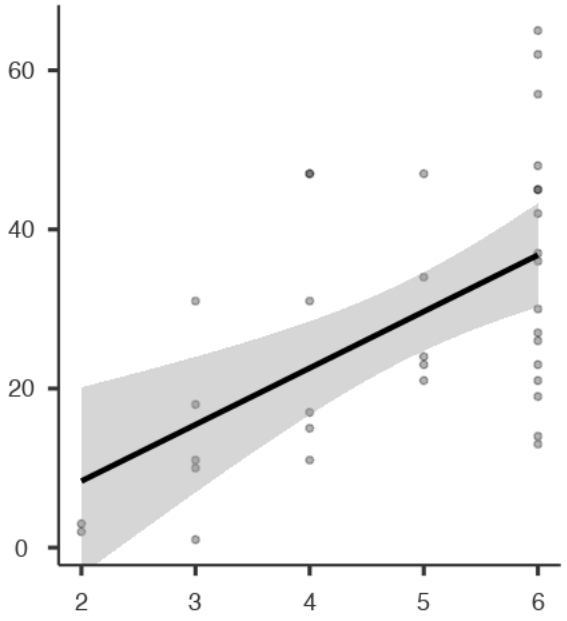

Fig. 5. Correlation between number of participants/players (x-axis, from 2 to 6) and number of errors (y-axis): Persaon's r = .622, p=.001

B. Qualitative Data

As explained in the Method part, a debriefing session was realized with all participants/players at the end of each game. Each participant/player was invited to comment freely their own behaviours, their difficulties, their limits or misunderstandings, etc. This debriefing session was always supervised by an expert in ergonomics or work psychology.

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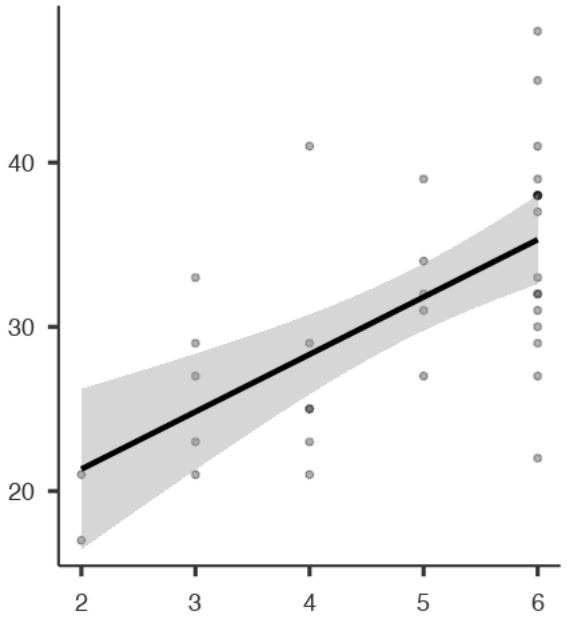

Fig. 6. Correlation between number of participants/players (x-axis, from 2 to 6) and time spent to complete the mission (y-axis, in minutes): Persaon's r = .557, p=.001

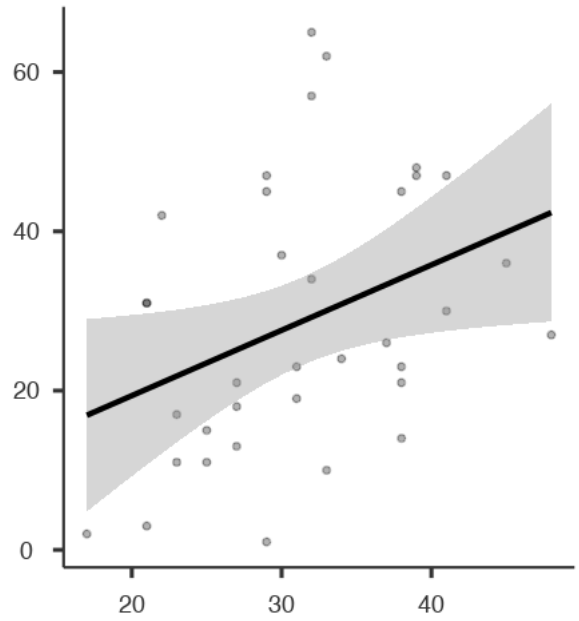

Fig. 8. Correlation between the numbers of errors (x-axis) and time spent to complete the mission (y-axis)

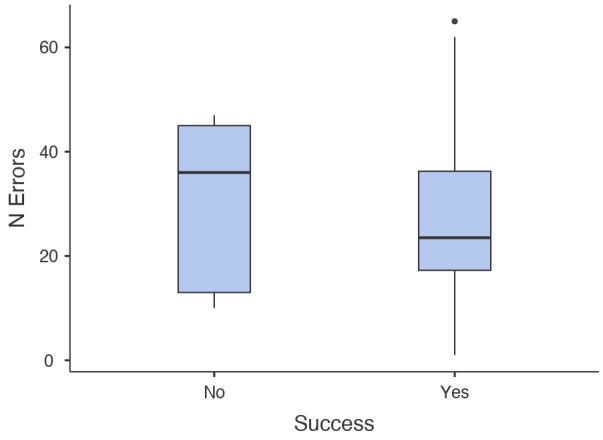

Fig. 7. Impact of the number of errors on success

A lot of interesting qualitative and complementary information has been obtained during this debriefing session. For instance, from a spontaneous manner, some participants/players evoked specific difficulties such as: "s/he didn't understand what s/he must to do, because s/he didn't listen me!" "S/he didn't respect the instructions given by the captain." "I was too stressed because the other individuals didn't' give feed backs about their own behaviours".

Moreover, some verbalisation allow to determine some problems or difficulties in the immersive environment or in the game design. For instance, some participants underlined the existence of irregularities in the synchronisation between the physical location of each other participants in the digital environment and their voices (e.g., "I saw him/her in front of me in the submarine but I heard her/his voice on the right side").

As we can see, debriefing provides information about the immersive environment itself (i.e., its usability, its acceptability, some technical problems) but debriefing is particularly crucial to allow participants/players to reflect on their experience, support each other, share perspectives, identify difficulties and finally, to develop understanding about some non-technical skills involved .

IV. Discussion

First, our results obtained with 35 participants tend to confirm that technology such as an immersive environment created by Virtual Rangers can offer a new and positive model for assessing non-technical skills. A crucial feature of non-technical skills is the fact that they can be developed through training, education and development programs and, besides the training, such non-technical skills can also be assessed using quantitative methodologies.

Second, we assume that the collaboration between scientists, industrial partners and designers is necessary to conceive a relevant assessment tool human-centred and oriented to non-technical skills.

Third, if the use of digital tool as immersive environment is relevant to assess non-technical skills, debriefing after the use is also important because it allows professional teams to reflect on their experience, support each other, share perspectives, identify learning opportunities and agree on improvement

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needs. In other words, we assume that an iterative and incremental human-centered design is a problem-solving technique that puts real people at the center of the development process, enabling us to create products and services such as immersive environments that resonate and are tailored to our audience's needs.

Our experiment has several limitations preventing generalization. For instance, several individual characteristics of each player/user (e.g., level of expertise, status in his/her company) were not assessed although we know that these individual characteristics can have an effect on participation or communication.

From an applied point of view, our immersive environment can be a complementary educational tool to assess and to teach non-technical skills. Non-technical skills are more and more important in industry for safety while some authors such as [23] discussed a mismatch between the goals of technical depth demanded by recruiters and line managers and the broader intellectual skills sought by corporate leadership. This can be described as the tension between needing graduates to be productive and to have safety behaviours today and the desire to harness and grow creative, innovative, and managerial talents. Non-technical Skills are more and more strategic to be successful in personal and professional life then are essential for a candidate when he tries to obtain any kind of job [24]. The quality of the industry, in terms of quality of the product, of the organization, of the services and of the workers' life and safety, strongly depends on the non-technical Skills possessed by personnel at any level. In other words, as an implication, universities and school of engineering need to equip students not just with intellectual and technical capabilities but also applied practical non-technical skills which make them more "work ready" to being focused in safety [25].

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