



MASTER - A multimethod system for the assessment and training of teamwork in simulated scenarios

Contract n° AO2016-07

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Deliverable 1

- Project outline
- Simulation and Non-Technical Skills.
- Definition of SPS profile of electrical workers
- Development of simulation scenarios
- Development of Non-verbal cues (NVC) tracking system

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Project outline

The aim of this study is to develop and test a set of observation and rating forms for the Situated Professional Skills (SPS), i.e. the blend of technical and Non-Technical-Skills (NTS) of workers involved in a simulation of electric tasks. In addition, we want to add a new method for observing behaviours based on non-verbal cues (NVC), like physiological data and gaze orientation in the operational environment. We aim at developing a new approach to simulation based on systems and indexes for monitoring team coordination. By automatically quantifying human behaviour using wearable and non-invasive sensors, we can find relationships between sensor data and team performance and thus identify optimal behaviour patterns that would lead to improved performance.

The project structure is outlined in fig. 1.

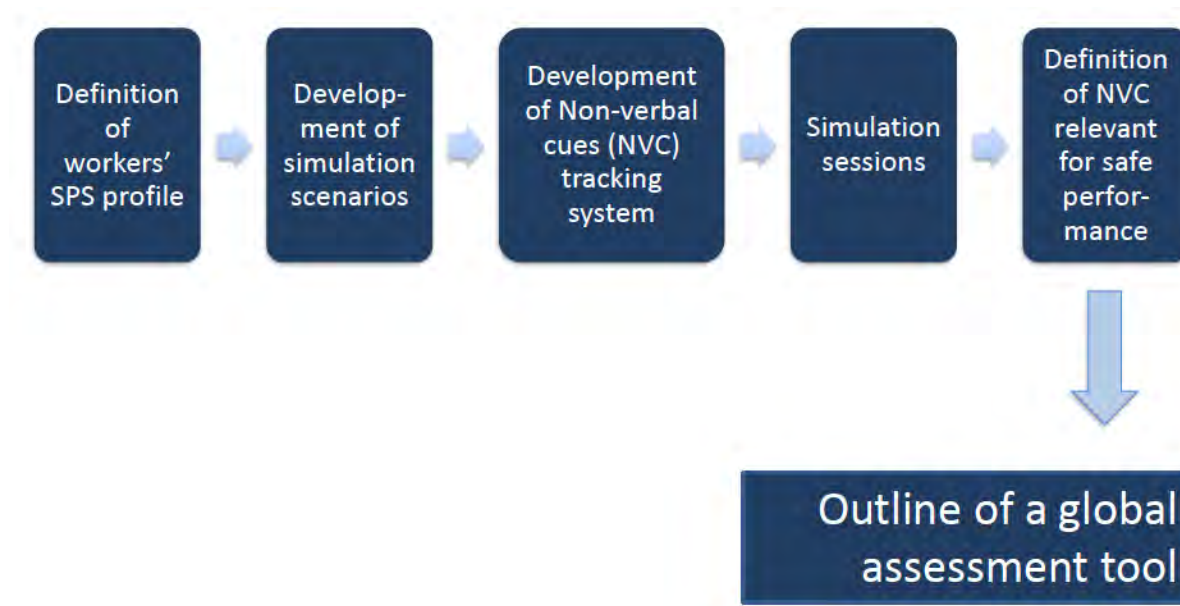


Fig. 1 - Project's flow of tasks

Simulation as a training method for safety

Simulation is one of the most acknowledged and widely used methods to train adults in many domains with the goal of promoting safety and performance efficacy on the workplace (Salas, Rosen, Held and Weissmuller, 2008). It is considered one of the best methods to transfer new knowledge, skills, procedures, and to shape behavior (Cook, Hatala, Brydges, Zendejas, Szostek et al., 2011). According to McGaghie and colleagues, simulation has the potential to transfer in the current practices the technical and non-technical aspects learned during the simulated scenario (McGaghie, Issenberg, Cohen, Barsuk & Wayne, 2011).

Taking into account modern work activities, simulation has been introduced in the aviation domain since the beginning of the 20th century. However, its effectiveness as a training method has been so well recognized that it progressively spread to other domains like healthcare (Owen, 2016), maritime transportation (Perkovic et al., 2008), road safety (Boyle and Lee, 2010), industry (Mujber, Szecsi, Hashmi, 2004), constructions (Zhao and Lucas, 2015).

Simulation has been adopted as a training method in the electrical domain as well, even though it is mostly used a training tool for new hires and apprentices, mainly focused on specific technical procedures. Simulation training for safety has been described in Zhao, Lucas and Thanet (2009), in order to increase electrical hazard awareness of construction workers. They developed a virtual environment simulation training program with interactive tools aimed at engage workers in safe work procedures.

Non-technical skills

Non-technical skills (NTS) are cognitive, social and personal skills, complementary to the technical skills, that contribute to the activation of safe and effective work performance (Flin, Martin, Goeters, Hoermann, Amalberti et al., 2003). They represent all those skills not pertaining the technical expertise of a given profession, but that play a key role for both work quality and safety. Notwithstanding several models have been proposed, we are still lacking a comprehensive model of all these skills necessary to guarantee the accomplishment of safe operations. This is probably due to the fact that the set of NTS widely vary according to the specific work environment and the specific activity (Thomas, 2018).

One of the most recognized categorizations of NTS divides them into two subsets: cognitive and social (see Table 1). The cognitive NTS are situation awareness, decision making and task management, while the social NTS are communication, leadership, and teamwork (Thomas, 2018; Flin, Yule & Rowley 2006).

CORE SOCIAL SKILLS

- COMMUNICATION
- LEADERSHIP
- TEAMWORK

CORE COGNITIVE SKILLS

- SITUATION AWARENESS
- DECISION MAKING
- TASK MANAGEMENT

Table 1 - Core domains of non technical skills (Thomas, 2018, p.10).

Situation Awareness

Situation Awareness (SA) describes the processes involved in the knowledge and understanding of the state of a work environment. Many definitions have been provided, but the most quoted is the one proposed by Endsley (1995), where SA is defined as the perception of the elements in a given environment, a space and time frame, the understanding of their meaning and the projection of their status in the near future. The SA tripartite model is framed within a wider network of influences between expectations, expertise, past experience, decision making, etc. (Endsley, 2000).

SA is therefore represented as a cumulative process that starts with the proper perception of the relevant pieces of information in the environment. If the person fails at this stage, the whole SA will be hindered, because no understanding and no forecasting will be possible. The reasons for failure at this early stage could be due to a lack of data, poor visibility of the relevant information, or a bad design of the interface. In addition, attentional problems may hamper SA, like the well-known fixation error or "tunnel vision", where the focus of attention is directed towards some areas in the visual field, or the attentional template is set towards some specific patterns and the rest of the environment is neglected.

The second stage of SA is the understanding of the perceived data. At this level, operators build a picture of the situation based on their interpretation, store it in their memory and integrate it with former knowledge. A possible threat at this level is due to the interference of previous knowledge or contextual patterns that distort the situation interpretation. One of the most frequent threats of this kind is the confirmation bias, i.e. the effect of inadequate mental models that force the operator to confirm his expectations, neglecting what actually disconfirms them.

Eventually, the third stage of SA is based on the projection of the situation in the near future. This is a form of complete SA, since enables the operator to anticipate the events and he is not surprised by unexpected occurrences.

The limits of SA are mainly linked to the limits of short-term memory. In case of information overload, human attention acts like a filter selecting only the elements that are supposed to be the most relevant. Unfortunately, past experiences, expectations, preconceptions, and heuristics guide our selective attention and sometimes we build a wrong representation of the situation (Flin, O'Connor & Crichton, 2008).

Decision making

High-risk socio-technical systems usually present an operational environment which is different from the ordered realm of the standard operating procedures. Operators often face unexpected situations and they must provide a safe and effective response. The process that starts from the identification of a mismatch between reality and the expected situation, notices anomalous events, performs a diagnosis of the current state, and builds a specific course of actions in order to cope with the situation is called decision making.

Decision making is therefore a process where an activity is chosen, implemented and evaluated according to its results. An effective decision making is based on the evaluation of both the positive and the negative aspects of the available options, but it is also necessary to foresee the possible outcomes (Flin et al., 2008).

Among the several models that have been proposed to describe decision making processes, we can see the classical model, the so-called “rational decision process”. However, it has been criticized by many scholars, since human processes do not seem to follow the path of absolute rationality. In addition, high-risk environments are characterized by uncertainty and time pressure and the rational decision making is based, by definition, on the knowledge of all the relevant variables and no temporal constraints. A more suitable model is therefore the “naturalistic decision making”, inspired by the strategies used by experts in making decisions in high-risk and ill-defined situations (Flin et al., 2008). The decision making is a cognitive process developing through several stages: from the assessment of the problem, to the diagnosis based on the matching between environmental cues and past experiences, the evaluation of the most appropriate response based on the anticipation of its probable outcomes, the implementation of the strategy and its eventual assessment.

Task management

This category refers to the activities performed by the operators in starting a task, monitoring it, managing the priorities and accomplishing the assigned task (Thomas, 2018). In high-risk operational environments the safe performance is maintained through multitasking: the operators often have to perform primary and secondary tasks in parallel. The management of the task is based on:

- task planning and preparation: goal setting, role distribution, sharing of expectations and information;
- workload management: understanding of the task complexity, available resources, task duration, operators expertise;
- priority allocation: capacity to prioritize the most important activities, making sure that they are performed thoroughly;
- duties delegation: a complex task needs a proper coordination of the team, where the duties are assigned to the right persons with clear timing and expectations;
- management of interruptions during the task: attention is a crucial resource for task management, any interruption could hinder the whole process; therefore, the capacity to manage interruptions is crucial for the quality and safety of the performance.

Communication

Communication is one of the core competencies of human beings, however, the vast majority of our knowledge about it is implicit. It is important to develop an explicit understanding of communication if the goal is the improvement of communication skills.

According to Kanki and Palmer (1993), effective communication enables the sharing of knowledge, the focused attention on a task, the development of interpersonal relations, the establishment of predictable behavioural schema, and is a fruitful tool for the management of the resources.

Many factors can hinder effective communication (Thomas, 2010). Cultural factors have a great role, especially the professional culture, because socio-technical systems are composed by professionals with many technical profiles, each one with his own language and mental models. Organizational culture can be another factor, because workers interpret a situation also according to their organizational frames (command line, hierarchy, blame culture, etc.)

Teamwork

High-risk organizations strongly depend on teamwork for the safe and effective management of the activities. Fundamental elements of teamwork are: mutual support, conflict resolution, coordination of tasks and information sharing (Flin et al., 2008).

According to Salas (1992), a team is composed by two or more people interacting in a dynamic, interdependent, and adaptive way, in order to reach a common goal or mission. In the team, every member has a role or a specific function and his/her belonging to the team is limited in time. Therefore, teamwork could be defined as the result of correlated behaviours, actions, thoughts, and attitudes that facilitate the accomplishment of the given task. Team members must have a common vision and understanding of the goal (CAA, 2004).

Salas, Rosen and King (2007) listed some basic teamwork principles: (i) a clear definition of roles and responsibilities among the team members, (ii) the belief that safety depends from cooperation and coordination, (iii) the presence of self-correcting behaviors and a strong adaptability.

A great portion of accidents in aviation, healthcare, army, oil drill, showed that the lack of team coordination was one of the leading factors, together with problems in resolving conflicts, misunderstandings, communication problems and lack of clear roles (Flin et al., 2008).

Leadership

Leadership has been defined as a process able to influence task's goals and the strategies of a team within an organization. It can have effect on team members in order to implement the strategies and accomplish the goals, with consequences on team identification and sustainability, and influencing the organizational culture (Yukl and Van Fleet, 1992). In addition, leadership can be a process able to influence others in the understanding and pursue of agreement about what to do and how to do it. It can facilitate individual and collective efforts for the accomplishment of common goals (Yukl, 2006).

Leadership is crucial for safety, especially concerning the use of authority, commitment to the standards, planning, prioritization, workload management and resources management (Flin et al., 2010). On the other hand, an ineffective leadership could have negative outcomes and even bring to accidents (Hofmann and Morgenson, 2004).

Leadership can be expressed in many forms, being more oriented to the relationship with the people, or more sensitive to the task accomplishment. Literature on leadership shows that there is not a single effective leadership style, especially if we apply this to safety. According to the situational approach to leadership, a good leader can adapt and change his approach in relationship with the situation. Emergency situations may require a change in leadership style due to the rapid change of scenario. The nature of his change is linked to the personality of the leader, but also to the organizational culture and expertise (Flin et al., 2008).

Stress and fatigue management

Stress and fatigue management have been proposed as further NTS for safety in socio-technical systems (Flin, et al., 2008). One of the most accepted definitions of stress dates back to seminal work of Lazarus and Folkman (1984), where they interpreted it as particular relationship between the person and the environment causing a condition of excessive effort and resource engagement able to put at risk personal well-being.

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Stress could be acute or chronic, varying according to the time period it exposes the person to environmental demands that may exceed personal resources (Mumaw, 1994). According to Cooper, Dewe and Driscoll (2001) theories about stress emphasise the role played by the personal evaluation of the situation. Subjective judgement of the demands will interact with expectations, expertise, and personality, to produce a feeling of stress in case the demands outweigh the available resources. The reactions are physiological, cognitive, emotional and behavioural. They can be framed in the model of coping styles a person will adopt to manage the stressors. Some of them may be dysfunctional and could lead to a poor performance (Cooper et al., 2001). Dysfunctional coping styles would result in the person denying the problem, or acknowledging it but shifting the responsibility to solve it to someone else, or just ruminating on it without any effective result.

Fatigue has been defined as the state of tiredness due to long working hours, to prolonged periods of lack of sleep and rest, and to job demands that are not synchronized with biological and circadian body rhythms (Caldwell & Caldwell, 2003).

Almost all the high-risk systems are organized with personnel shifts around the clock and this is a serious issue for safety. For instance, in healthcare fatigue is considered to be one of the main causes of mistakes (Lockley, 2004).

Environmental (noise, temperature) and psychological (stress) factors can contribute to fatigue. Its consequences are concerning cognitive processes (mainly the capacity to cope with unexpected and sudden events), motor skills (lower reactivity), communication and social interactions (irritability and error proneness).

From Non-Technical skills to Situated Professional Skills

Literature differentiates between technical and non-technical skills (NTS, Flin et al., 2008), but we state that professional competence is formed by three unsplitable pillars, which cannot stand alone: (a) operative competence, which is technical skills and knowledge, (b) cognitive competence, which is made of abilities such as decision making, problem solving, situational awareness, workload and stress management and (c) social competence, which consists in being able to communicate and work with others in an effective way. The least two aspects are usually referred as NTS, but we decline this definition to underline the complementarity and indivisibility of these three aspects.

Therefore, the situated professional skills could be represented as a three-legged stool, since each leg is necessary to keep it up. In Figure 2 we represent the model, where the three legs are the technical skills, the cognitive skills, and the social skills.

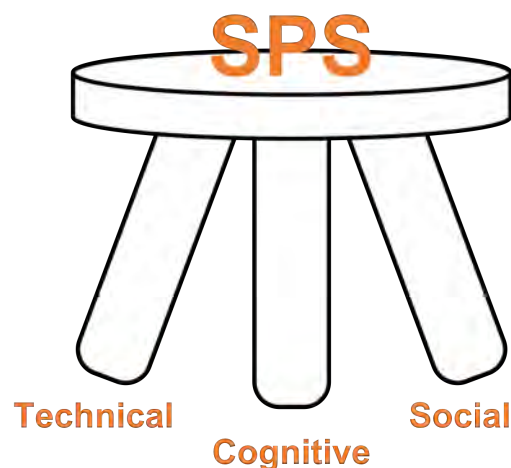


Fig. 2 - The stool model of the situated professional skills

Technical skills are abstract and decontextualized and they are usually learned in formal educational and training processes. They must be adjusted to match real world condition: this match is made by the use of cognitive and social skills. Any task of any job involves somehow all these three aspect of the professional competence.

These abilities as a whole are defined Situated Professional Skills (SPS) because they represent the application of the skills of a practitioner in his own every-day work.

SPS are usually learned with practice, on the job training and with coaching; we aimed to promote this learning with simulation training in the electricity distribution domain.

Simulation-based training for SPS in the electricity domain

To the best of our knowledge, the training of skills that are not merely technical or procedural in the electricity domain is not quite widespread. Saurin seems to be the only researcher that published papers on scenario-based training of NTS for electricity operators. In Wachs, Righi and Saurin (2012), the authors conducted several interviews of electricians following the Critical Decisions Method, i.e., asking them to explicitly verbalize their decisions and thoughts in several critical conditions. In addition, they

spent several hours on the field, observing the workers during their every-day activity. As a result, they outlined a list of 12 NTS for electricians. The list is presented below:

1. To discuss with the operation team defining procedures that should be taken and obtaining line information
2. To discuss with the field team reaching a common understanding on the situation
3. To discuss with the consumers and population the status and risks of line maintenance procedures
4. To express doubts, fears and requests for help from other team members
5. To identify structure, lines or equipment that are non-standard, damaged or have failed
6. To identify visible signs in the environment that indicate difficulties in doing the task or the probable cause of damages to the line
7. To develop strategies to identify line defects
8. To develop work strategies, after the defects have been identified
9. To plan and to check the equipment and materials that are necessary to undertake the task
10. To distribute the tasks between team members and to do the task accordingly
11. To identify causes of stress and fatigue
12. To develop strategies to cope with stress and fatigue situations

In a further research, Saurin, Wachs, Righi and Henriqson (2014) proposed a framework for the design of scenario-based training of grid electricians within the resilience engineering perspective. The same framework has been further tested in a comparison between physical and virtual scenarios (Yamao et al., 2015).

Taking into account the works of Saurin and colleagues, we decided to apply their method to the Italian electrical work context. Precisely, we wanted to:

1. outline the SPS profile of electrical workers
2. build a training toolkit based on high-fidelity simulation
3. correlate the observation of SPS with data concerning physiological parameters

Definition of SPS profile of electrical workers

The effectiveness of simulation is strongly dependent on the debriefing session, since learning actually occurs when it is based on proper feedback aimed at stimulating metacognition and reflection about team dynamics. The ability to analyse each other's performance retrospectively is crucial when it is focused not only in talking about what went well and what did not, but also on why it went well and why something else did not.

The debriefing session, after the scenario, is the core of the simulation, since it allows participants to integrate the experience with the theoretical frameworks and the procedural guidelines. Notwithstanding the evidence of the relevance of NTS for the safe and efficient accomplishment of operations, the observation, assessment and feedback about these skills is particularly complex, because the process needs expert observers and the feedback is often provided in judgmental and ineffective ways (Rudolph, Simon, Dufresne, and Raemer, 2006).

Therefore, a proper tool for observing specific behaviours during simulation scenarios is of paramount importance, especially for the balanced training on SPS. Notwithstanding the presence of some tools for the observation of teamwork and communication during simulated scenarios, there is a lack of structured tools for the observation of SPS in electricians working on electricity distribution power lines. We developed an innovative training method based on healthcare high fidelity simulation methodology. Its novelty is due to the formalized blend of technical and non-technical skills, the development of a validated checklist for the observation of SPS for electricians, and the visualization and analysis of NVC that underlie an effective teamwork. The debriefing after the simulation will therefore enrich the learning process and foster the adoption of proper attitudes for safe team performance.

We first performed an extensive literature review about NTS and simulation training for electricity distribution operators (EDOs). Due to paucity of published papers on simulation of electricity distribution scenarios and the absence of research about evaluation of electricity distribution operators' NTS, we based our study on the literature of NTS observation tools in healthcare (Gaba, Howard, Flanagan, et al., 1998) and the work of Wachs, Righi and Saurin (2012).

We started our investigation on other professions, taking into account the tools that were developed for simulation-based training. We adapted items referring to NTS for healthcare professionals (situational awareness, communication, teamwork, decision making, leadership) adapting them to the electricity distribution context. The behavioural markers obtained were therefore SPS indicators for EDOs, and they could be used as observational tool for simulated activities.

We held a series of meetings with representative samples of professionals (engineers and operators), thereby working on the adaptation of the tools to the Italian electricity distribution context. Each meeting was held by three expert psychology researchers, and involved at least one or two electricity distribution experts.

We developed a first draft of the tool based on a list of SPS such as:

1. Knowledge of expected conditions
2. Observation of real conditions
3. Understanding real conditions
4. Implementation of safe working conditions
5. Third-Party communication

6. Maintaining attention despite disturbances
7. Team communication/collaboration
8. Documentation usage
9. Stopping the work due to possible fraud
10. Stopping the work due to unsafe conditions

Then, we led two focus group with a new sample of practitioners to validate the content of the items and to check their comprehensibility. Finally, we designed a tool for the overall assessment of the performance of electricity distribution operators, assessing three SPS: (a) Task management, (b) Customer management and (c) Teamwork. The table below (Table 2) reports the items and the behavioural markers.

Task Management

1	Tools preparation	<input type="radio"/> Does not prepare the tools before starting the task <hr/> <input type="radio"/> Prepares some of the tools in advance, but then, during the task, has to stop to get some other tools <hr/> <input type="radio"/> Prepares all the necessary tools and materials
2	Risk Assessment	<input type="radio"/> Starts the activity before the necessary assessments (e.g. check of the metal parts, check of the integrity of the devices, check of all the items present in the scene) <hr/> <input type="radio"/> Starts the activity after checking only some of the items <hr/> <input type="radio"/> Starts the activity after all the necessary checks (e.g. checks the metal parts, checks the integrity of the devices, checks all the items present in the scene)
3	Personal Protective Equipment (PPE)	<input type="radio"/> Not all the necessary items of the PPE are used <hr/> <input type="radio"/> Uses some of the PPE incorrectly (e.g., helmet visor up) or some of the PPE items are not necessary <hr/> <input type="radio"/> All the necessary items of the PPE are used
4	Work documenta_ tion (e.g., work planning, legal documents, etc.)	<input type="radio"/> Is not read <hr/> <input type="radio"/> Is read only after having started the activity <hr/> <input type="radio"/> Is read before starting the activity and, if necessary, even after
5	Tools organization	<input type="radio"/> Materials and tools are haphazardly stored, he does not find them because they are left around or hinder the activity

	<input type="radio"/> Materials and tools are in place, but sometimes they are not at hand
	<input type="radio"/> Materials and tools are stored orderly, effectively and at hand
6	<p>Unexpected events management</p> <input type="radio"/> Acts like there was no unexpected or anomalous situation (e.g., mismatching data, damages, tamperings or particular characteristics of the environment)
	<input type="radio"/> Changes the activity in order to manage the unexpected or anomalous situation
	<input type="radio"/> Stops the activity and looks for further information (e.g., talks about it with the colleague or the operation center, seeks for further details, etc.)

Relationship with the client (to fill only in case the client is present in the scenario)

7	<p>Information to the client</p> <input type="radio"/> Does not provide the client any information about the activity
	<input type="radio"/> Gives the client information about the activity only if requested or after having started the activity
	<input type="radio"/> The client is informed about the activity in advance
8	<p>Client management</p> <input type="radio"/> Is not able to manage the client (e.g., has a conflict, the client doesn't follow his instructions, is distracted by client's behaviour)
	<input type="radio"/> Is able to manage the client, but only after he hindered the activity or had an argument with him
	<input type="radio"/> Makes sure that the client does not interfere during the activity (does not disturb, keeps him calm)

Teamwork (to fill only in case two or more operators are present in the scenario)

9	<p>Coordination</p> <input type="radio"/> Works without talking with the colleague about what to do
	<input type="radio"/> Talks with the colleague only after having started the activity
	<input type="radio"/> Starts the activity only after talking with the colleague about what to do
10	<p>Situation assessment</p> <input type="radio"/> Rarely talks with the colleague and the subject is not related to the current activity
	<input type="radio"/> Discussing about the activity does not brings proposals, says "yes" to everything or does not share his opinions

		<ul style="list-style-type: none"> ○ Discussing about the activity brings suggestions on how to operate, if he does not agree with the colleague, he explicitly shares his opinion
11	Listening to the colleague	<ul style="list-style-type: none"> ○ When his colleague is speaking, he does not reply, nods, or he even talks over him ○ When his colleague is speaking, sometimes he does not reply or even talks over him ○ When his colleague is speaking, he gives him a feedback (explicitly confirms what he has just done or heard what the colleague said)
12	Requests to the colleague	<ul style="list-style-type: none"> ○ He does not make requests to the colleague ○ The requests are generic or ambiguous (e.g. "give me that thing") ○ The requests are detailed and complete (e.g. "could you fetch me the screwdriver which is in the toolbox, on that table?")
13	Updating the colleague	<ul style="list-style-type: none"> ○ He does not update his colleague about what he's doing (which step of the activity) ○ Updates his colleague only if explicitly requested ○ Updates his colleague even if not explicitly requested
14	Management of risky behaviour and violations	<ul style="list-style-type: none"> ○ His colleague does not have risky behaviours and violations ○ Does not point out to his colleague his violations and risky behaviour ○ He points out to his colleague his violations and risky behaviour ○ Stops his colleague and points out his violations and risky behaviour

Table 2 - The SPS Simulation checklist

The main goal was to list only the observable behavioural markers, while avoiding items that were too generic or that were inherent to unobservable mental states. Since the list of items had to be suitable for the Italian context we asked the practitioners to describe their tasks. We tried to develop a tool that was easy to use during the debriefing session of the simulation training aiming to make it quick to complete and easy to understand for practitioners who are unskilled in debriefings and NTS. At the end of the development process, we developed a list of 21 items divided into three domains, called SPS simulation Checklist.

We defined detailed behavioural markers for each item, in order to anchor the performance rating on a three-point rating scale. Each level of performance (poor, medium and good) had a specific behavioural marker defining the observable performance (see Annex 1).

All the items underwent an iterative refinement process in order to reference only observable behaviours. For instance, instead of asking if every team member knew about his or her role (which is not observable), the item asked if the roles were clearly and explicitly identified.

We adopted this kind of scale because, in a previous test, we observed that a dichotomous scale was perceived to be too judgemental by respondents, since they only had two options, i.e., good or poor performance. Therefore, we adopted a three-point scale, which presented a simple layout articulated enough to catch the information about the performance of the participants to the simulation training.

SPS Questionnaire

We wanted to measure the medium-long term effects of the simulation training. We decided to develop a self-report instrument to this purpose, a questionnaire which evaluates the same areas of the SPS simulation Checklist.

We started from the behavioural markers used for the SPS Simulation Checklist and the qualitative analysis from the focus groups and the meeting with experts and practitioners. It was made of 28 items with a 5 point Likert scale (Never, Rarely, Sometimes, Often, Always). A pilot refining and validation study was conducted involving a sample of 29 participants belonging to the north-west operational area of e-distribuzione, the main electricity distributor company of Italy. It was performed an item analysis to check the reliability and internal consistency of the questionnaire. Two items were deleted due to low item-total correlation ($< .2$) leading to a higher reliability. The final questionnaire is made of 26 items, it has a Cronbach's α of .84 and a mean inter-item correlation of .17. The exploratory factor analysis shows a one factor simple structure.

We named this tool SPS Questionnaire and it measures specific SPS of medium and low voltage EDO (see Annex 2). The following list presents the items of the SPS Questionnaire:

1. I schedule my work in order to do the most complex tasks when I'm rested
2. While I am working I find myself thinking to other things (e.g., the next task to do or things unrelated to the job)
3. When I notice a wrong behaviour, I stop the colleague and I point it out to him/her
4. When I notice an anomaly, I stop working and make an assessment of the situation
5. While I am working, I always have everything I need at hand
6. I offer my help to a colleague when she/he is doing a complex task
7. Before starting a task, my colleagues and I brief each other on "who does what" ("I do this, you do that")
8. I happen to get into a heated argument with my colleagues
9. Before starting a task, I discuss what to do with my colleague
10. I observe and inspect the environment I will operate in to spot and evaluate possible anomalies
11. I keep my toolbox tidy
12. When a colleague is doing a task, if I notice a problem I point it out to him/her
13. When dealing with a complex task, I wonder whether I have already faced similar circumstances

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14. When a colleague offers his/her help, I accept it
15. When I notice an anomaly, I discuss about it with my colleague, the team leader, or the unit leader
16. I check and assess the integrity of the elements I am going to operate on
17. Before starting a task, I organise all the necessary tools and materials
18. I read the whole documentation (i.e. work plan, blueprints, etc.) before starting a task
19. I double check before starting a potentially dangerous action
20. I test all the metal parts nearby the operating field with an electrical tester
21. I wear all the PPE (personal protective equipment) required by the procedure
22. When I am tired or unable to focus I try to have a break
23. I monitor my colleague while he/she is performing a complex task
24. Before leaving the offices in the morning, I schedule my working day
25. While working, I tell my colleague what I am doing in order to keep him/her updated
26. I happen to get into a heated argument with a client or a contractor
27. During complex tasks or critical phases, I make sure if I have understood what I have been told (e.g., I repeat my colleague's request and, before doing it, I let him/her know that I'm going to do it)
28. While performing a task, I stop working and take the stock of the situation

Development of simulation scenarios

Simulation training promotes situational awareness, self-monitoring, decision making and cooperation with team mates and co-workers while working. We also aim to promote compliance with rules allowing participants to discuss, understand and introject them in the debriefing phase. Therefore we expect better teamwork abilities (assertive communication, open and helpful attitude, etc), better task managing and higher safety levels (decreased number of near miss and accident).

Simulation needs to respect some characteristics to reach these goals. Scenarios must be realistic in term of script and simulation environment. Immersivity have to be high.

With the term immersivity we mean the level to which the participants to the scenario lose their feeling of being involved in a simulation and perceive the events in the scenario as similar to the everyday experience. The higher the immersivity, the more likely the observed behaviour will be similar to that displayed in normal work conditions.

Even if some features of the simulation could not be the same as in the real world, there are some countermeasure to implement to keep immersivity high. According to Hagiwara et al. (2016), a proper scenario design should take into account the events and dynamics which could promote or hinder immersivity. They developed the "Immersion Score Rating Instrument", whose main concepts are listed below (Table 3), adapted to our goals.

Triggers	Examples
Destructive interaction between participants and persons outside the scenario	<ul style="list-style-type: none"> • A participant asks the instructor for directions • An instructor asks questions or gives instructions
A participant expresses that the expected equipment is missing or not functioning normally	<ul style="list-style-type: none"> • Expected equipment is missing • A participant has trouble using the existing equipment
Disturbing jumps in time and/or space	<ul style="list-style-type: none"> • A jump initiated by an instructor • A jump initiated by a participant
All or part of the operations are pretended	<ul style="list-style-type: none"> • An instructor asks a participant to pretend a moment • A participant claims to perform one operation without doing it
Unnatural interaction with the client and/or another person in the scenario	<ul style="list-style-type: none"> • A participant acts or communicates in a way that would be unnatural towards a client in a natural context • A participant acts or communicates in a way that would be unnatural towards another person in a natural context

Uncertainty in what is expected or can be done in the simulated scenario	<ul style="list-style-type: none"> • Participants discuss technical aspects of the scenario • A participant expresses uncertainty about what is expected or can be done in the scenario
Technology that would not be part of a natural context disturbs the participants	<ul style="list-style-type: none"> • A simulator does not work as intended • A camera/microphone disturbs a participant • Other equipment that does not belong to the scenario disturbs a participant
Natural responses to stimuli in the scenario	<ul style="list-style-type: none"> • A participant responds to something non related to the simulated activity
Natural interaction with the simulator	<ul style="list-style-type: none"> • A participant performs actions or investigations that a simulator can not provide answers to

Table 3 - Threats to simulation immersivity (modified from Hagiwara et al., 2016)

We followed a backward design to develop the scenarios: we started defining the educational objective and then we went back until the definition of the script.

The methodology of the backward design consists of the following phases for each scenario:

1. Clearly define the educational objectives with experts. Objective have to be adequate to the knowledge and skills of the participants and to the activities and tasks usually performed. We decided to focus on the most common medium-low voltage tasks.
2. Identify which SPS are involved in each scenario and define the equivalent behavioural markers (BM). Before starting the writing of the script, we should be aware of which behaviours indicates a good performance.
3. Precisely define the script of the scenario in such a way that it requires the BM previously identified. Most of the times, scenarios are adaptation of real cases (incidents or near misses) analysed by the experts in their professional experience. They are modified to explicitly require the BM related to the objectives of the scenario. Not realistic situation are avoided because they could generate not realistic behaviours.
4. Development of the simulation room, using real tools and equipment modified, if needed, to reach the goal of the simulation. Realism is a priority.

Five scenarios have been developed. Each scenario has been described according to this schema:

- Task Assigned
- General Scenario Description
- Overall Learning Objectives
- SPS
- Operational Context
- Materials
- Setting Set-up
- Participants
- Scenario Saving Items

- Expected Duration
- Detailed Sequential Description of Scenario

The five scenarios are outlined in Table 4.

Scenario	Title	N° of workers	Task	Overall Learning Objective(s)	Physical Risk Type
1C	The Real Electricity Meter	1	EM with EM substitution	Potential risks management	Electric, Low-Dexterity Injuries
2C	The Construction Site	2	Temporary supply installation	Securing the work environment	Electric, Fall, Low-Dexterity Injuries
3C	Demolition	1	Supply cessation and EM removal	Fraud identification	Electric, Low-Dexterity Injuries
4C	End Of Works	2	Temporary supply removal	SWP application	Electric, Fall, Low-Dexterity Injuries
5C	The New Three-phase	1(+1)	Three-phase EM with three-phase EM substitution	SWP application	Electric, Low-Dexterity Injuries

Table 4 - The five scenarios outline (EM=Electricity Meter; SWP=Stop Work Policy)

Taking into account the SPS and the observation checklist, the five scenarios were designed in order to cover a wide range of situations (Table 5).

SPSs	1C	2C	3C	4C	5C	TM01	TM02	TM03	TM04	TM05	TM06	TM07	CM01	CM02	CM03	TW01	TW02	TW03	TW04	TW05	TW06	TW07	TW08	TW09	TW10	TW11
1. Knowledge of expected conditions	X	X	X	X	X	X		X	X				X	X												
2. Observation of real conditions	X	X	X	X	X		X				X	X					X		X							
3. Understanding real conditions	X	X	X	X	X		X	X			X	X				X			X	X						X
4. Implementation of safe-working conditions	X	X	X	X	X	X	X	X		X				X			X			X	X			X	X	
5. Third-Party communication	X	X			X								X	X	X											
6. Maintaining attention despite disturbances	X									X	X			X				X								
7. Team communication/collaboration		X		X	X							X				X	X		X	X	X	X	X	X	X	X
8. Documentation usage		X					X	X																		
9. Stopping the work due to possible fraud			X								X	X														
10. Stopping the work due to unsafe conditions				X	X						X	X														X

Table 5 - The matching between scenarios, SPS and the specific behavioural markers (TM=Task Management; CM=Communication; TW=Team Work.)

In addition, in order to help the trainers to observe the key points of participants behaviour during the simulation, we designed for each scenario a detailed schedule of triggers, events and related SPS involved. As an example, see the table below (Table 6), relative to Scenario 1C: The Real Electricity Meter.

Action/behaviour	Disturbance	SPS
Prepares tools and materials		1
Controls the environment	Label OUT OF ORDER Client	2 - 5 - 6
Wears personal protective equipment	Client	1 - 4 - 5 - 6
Correctly finds the EM	N° of meter different from documentation Display not working Client	2 - 3 - 5 - 6
Disconnects the EM	Client	3 - 4 - 5 - 6
Verifies absence of power outwards	Client	2 - 4 - 5 - 6
Disconnects, identifies, and isolates the cables	Client's cables of the same color Client	2 - 4 - 5 - 6
Removes the old EM	Client tries to help	5 - 6
Installs and programs the new EM	Client's cables of the same color Client	3 - 5 - 6
Correct ending of the EM change procedure	END OF SCENARIO	

Table 6 - Outline of scenario triggers and SPS. SPS are numbered as follows: 1.Knowledge of expected conditions; 2.Observation of real conditions; 3.Understanding of real conditions; 4.Implementation of safe-working conditions; 5.Third-Party communication; 6.Maintaining attention despite disturbances.

Standardized client

Relational SPS can be assessed through the relationship operators have with their colleagues, and with other roles that may be involved in the simulation, both indirectly (team leader, Central Operation Room), and directly (clients, passers-by, other professionals not working in e-distribuzione). In both cases, the representation of these roles is transferred to the instructors, which should interact with the participants in order to trigger some specific behaviour coherent with the learning objectives. Usually, the client's role is to engage participants in a particular relationship (conflictual, unsafe, cooperative, etc.), that will be one of the main topic of reflection during the debriefing.

For instance, the client in scenario 5C represents a relational issue to be managed but also a safety issue, because his curiosity, his willingness to help the operator giving him the tools and touching the devices is a potential threat for both of them.

The simulated client is a critical role and his script must be carefully designed specifying each of the following aspects:

- learning outcomes it should aim for
- emotional state and approach to the situation (how he relates with the situation and the participants in general)
- specific behaviours during the scenario
- triggers to specific events
- mode of response to specific behaviours

- break points (e.g., what makes him resistant to the highest level) - it's a trigger specification
- possible scenario-saving role or confederate role

The reason to specify all these details is grounded in the need to reduce risks such as:

- if every simulated client would represent the role in a different way, according to his mood or interpretation, each scenario would be different, it may stimulate different SPS, and there won't be any standardization.
- the lack of specifications may lead the actors to exaggerate the role and threat its credibility; in other words, the immersivity may be hindered because the relational dynamic may appear unrealistic and fake.
- the lack of a predefined mode of response to triggers runs the risk not to pursue the learning outcomes that were set for the scenario (e.g., if the operator shouts at the client, he should react accordingly and consistently).

Some possible specifications of the client across the scenarios:

- the client is having a strong emotional reaction: what are his needs? What emotions is he expressing? What are the reasons of his behaviour?
- the client is possible source of information: is he used as a useful source? Are the operators able to get information effectively, discerning what is useful from what is not?
- the client is a possible threat/distraction: he hinders the operator, he touches things he shouldn't be allowed to touch, he verbally disturbs the operator.

Development of Non-verbal cues (NVC) tracking system

Training ground

On the training ground, the subject is the focus of multiple sensors and recording devices. Both the video and the audio are recorded from different angles. The audio is recorded from three different devices: the action camera YI 4K from XIAOMI, the external microphone Zoom H6 for the surrounding soundscape, and finally directly on a microphone placed next to the subject's mouth. The video follows two different approaches. The action camera YI 4K from XIAOMI takes the subject's perspective and shows what he is actively looking at since it is mounted directly on his helmet. The four LIFE cameras are placed to give 4 different fixed perspectives on the scene giving a general view of what is happening (Figure 3).



Fig. 3 - Location of the cameras

Finally, we measure a number of physiological data using Zephyr belt placed directly on the skin of the torso. The physiological data of interest comprises heart rate, breathing rate, heart rate variability, and activity measures. The heart rate and breathing rate measures respectively the number of beats per minutes and number of breaths per minute. Monitoring heart rate as well as breathing rate is usual practice nowadays in sports and intense activities (Achten and Jeukendrup, 2003). It is usually used as an indicator of individual's training status and is impacted by the type of activity performed. The heart rate variability is a measure of the variation in the time interval between individual beat detections. This variability has been regarded as a proxy for 'vertical integration' of the brain mechanisms that guide

flexible control over behavior with peripheral physiology, and as such provides an important window into understanding stress and health (Thayer et al., 2012). Lastly, the activity is a direct translation of the movement of an accelerometer and symbolized by vector magnitude units showing how the various axis points are added (lateral, sagittal and vertical); ~ 0.2 VMU for walking and ~ 0.8 for running. This last parameter can be used to explain part of the variance underlying the different measured rates (heart and breathing).

The choice of using such belts and measure these specific parameters falls behind three rationales: the ease of use, the visualization, and the literature associated. First, the belts are easy to set up, small, and portable. They work wirelessly and show impressive battery life. They are furthermore non-invasive, and allow the technicians to move freely. Second, the software provided with the belt is visually easy to read, with information displayed in real time. The evolution of the different measured rates is also displayed on screen for easy read out. Multiple belts can be used and will be displayed separately in the software window. Third, as mentioned, these parameters have been explored in multiple context of physical activities and stressful events. Two other parameters related to stress, electrodermal activity and pupil dilation, were left out of this experiment since they required additional devices that would clutter too much the non-invasiveness of this experimental setup.

Remote control room

The remote control room allows for external viewer, members of the evaluation panel, and co-workers to evaluate the performance of the subject without being directly present on the training ground. All of this is supported because video recordings, audio recordings, and physiological data are streamed from the training ground to the remote control room. Every signal recorded on the training ground is sent to an external computer (except the LIFE camera that are connected to their own house-designed hub). The computer receives a live stream of the footage acquired by the Action Cam YI 4K by Xiaomi over a local WIFI signal. This live stream is supported by the mobile application Vysor. We also display a live update of the physiological data acquired at a frequency of 1Hz. Both signals are subsequently rearranged over the space of one screen. Finally, this screen is duplicated via HDMI cable to a screen in the remote control room. The recordings from the four LIFE camera are mixed with the audio coming from the mouth microphone (amplified thanks to a sound amplifier) and are sent over HDMI cable to a beamer and multiple speakers in the remote control room.

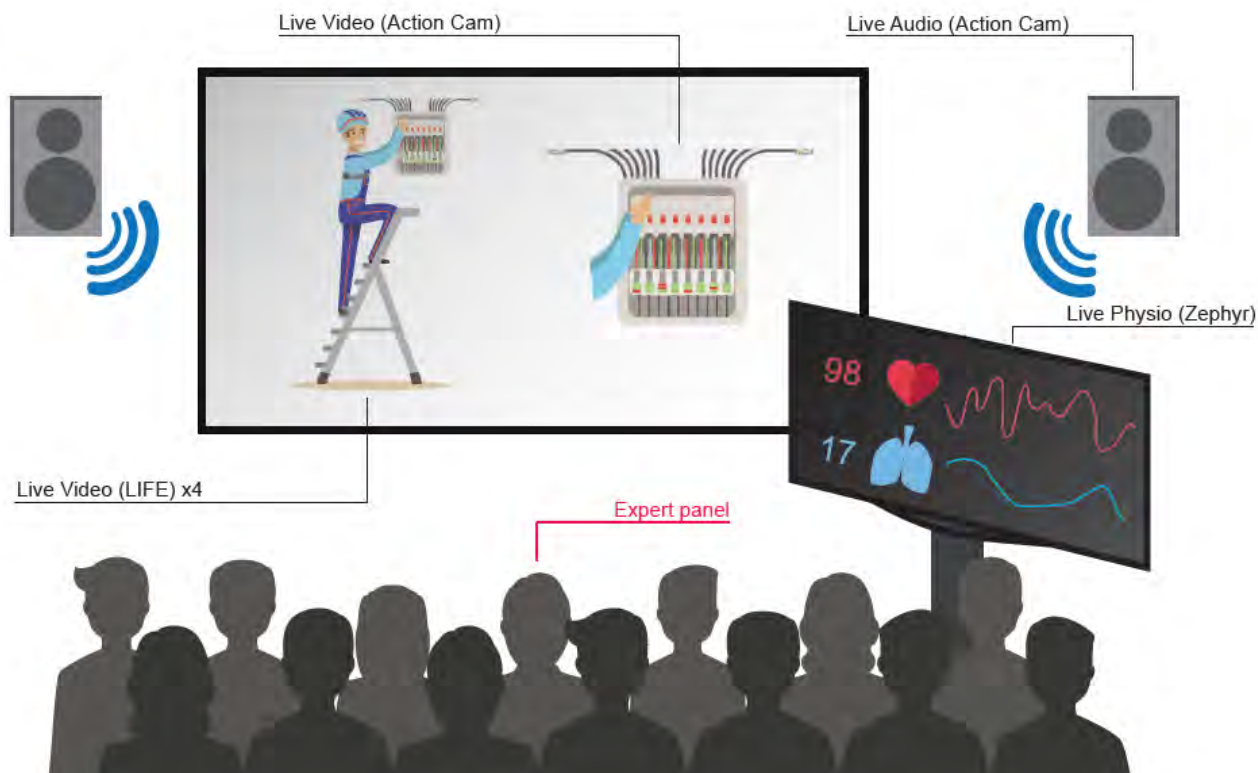


Fig. 4 - Perspective from the debriefing room

This configuration offers a complete overview of the action happening on the training ground with both overall and detailed representations of the operations at play. Based on such rich environment, the expert panel and co-workers can give constructive feedbacks on the subject's actions.

After the recording sessions, the different medias were put together in 'multi-views' videos. This created a single media that display the point of view from the 4 LIFE cameras, the frontal action camera, as well as the evolution of the physiology of the technicians. These 'multi-views' videos were created using Adobe Premiere. Faces were also in some cases blurred to protect privacy. This material allows for a global understanding of the task at end and could be used as learning material for the technicians.

Complete device list

Training ground -

- 3 Manfrotto Trepied Befree MKBFRA4-BH
- 1 Zoom H6 portable Numeric recorder
- 1 YI 4K Action Camera Full HD 12MP WIFI 155° wide angle 4K/30 - black
- 1 Toshiba Exceria M302 microSDXC U3 (64Go, Class 10)
- 1 smartphone connected with the app Vysor
- 1 USB-B cable (20cm)
- 1 LIFE system 75.1HD4104 - 4/9CH containing 4 LIFE camera, the HUB system, and the corresponding cables
- 1 Switching power supply KD2054/12 (12Vdc - 5A)
- 1 Monitor
- 1 Laptop
- 3 ZEPHYR belts with the corresponding ZEPHYR sensors

- 1 SubZero SZW-50 Microphone system with 2 wireless microphone headsets
- 1 Behringer Micromix MX400 Line Mixer
- 1 jack cable 3.5mm
- 2 HDMI cable (20m)

Remote control room –

- 2 big screens (1 television, 1 projected)
- 1 beamer
- 1 sound system linked to the beamer

Procedure

The whole simulation session is managed by psychologists with expertise in high-fidelity simulation in cooperation with technical personnel of e-distribuzione. After a preliminary introduction, the participants visited the simulation room in order to familiarize with the environment. They were told how to operate the devices, that during the simulation they would have worked with the electricity turned on (respecting safety regulations), that they should have behaved “as if” they were in a real work situation. This phase was crucial to let the participants immerse themselves in the scenario, understanding the limits and characteristics of the simulation (e.g., the use of the work cell phone, the ICT tools, the task documentation and the devices).

Every participant took active part to at least one scenario and was observer of all the others. The participants in the debriefing room could watch the simulation on a wide screen with multiple perspectives from the several cameras (fig. 5).

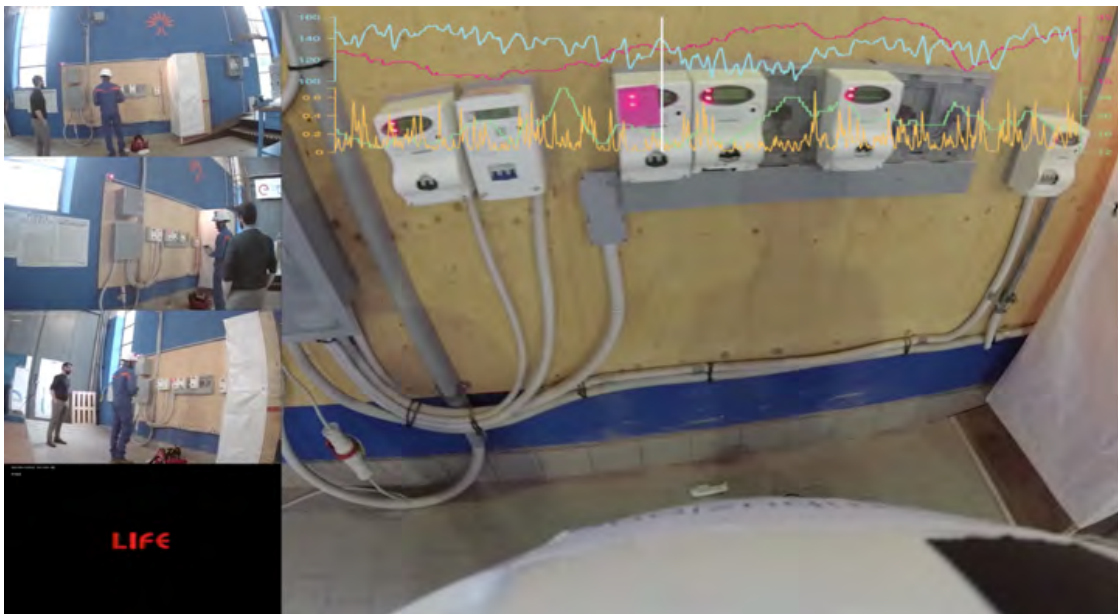


Fig. 5 - The view from the monitor in the debriefing room

In addition, the observers had a dedicated monitor for the physiological parameters (fig. 6).



Fig. 6 - The monitor with the physiological parameters

Scenario's setup

The outline of the activities to be done before and after the scenario, in the simulation room and in the debriefing room, are presented in Table 6

SIMULATION ROOM	CLASSROOM
	<ol style="list-style-type: none"> 1. Read the description of the scenario 2. Choose the participant(s) 3. Give the RDL to the participant(s) 4. Bring the participant(s) in the sim room
<ol style="list-style-type: none"> 1. Set the chest-band sensor 2. Sit the participant on a chair (for 2min) 3. Set the microphones 4. Set the helmet with the action-cam 	<ol style="list-style-type: none"> 1. Assign observation task to every observer (who to observe) 2. Provide checklist
SIMULATION	Participant(s) observation
<ol style="list-style-type: none"> 1. Sit the participant on a chair 2. Remove the microphone 3. Charge the microphone 4. Remove the helmet 5. Charge the action-cam 6. Remove the chest-bend sensor 7. Charge the chest-bend sensor 	<ol style="list-style-type: none"> 1. Fill in the checklist
Set the simulation room for the next scenario	DEBRIEFING

Table 6 – List of the activities to do in the simulation room and in the classroom

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Setting

The setting was the simulation center of e-distribuzione, usually adopted as a training center for newly hired operators. The simulation room was equipped with electricity meters and other devices that are typically part of operators' job. Special boards were used to separate the areas and reproduce small spaces (e.g. a basement where the meter is installed).

The cameras were positioned in order to have a full view of the scene from many perspectives, plus the action cam on operators' helmet. The operators that took part to the scenarios also had a wearable microphone, in order to leave them free to move and reduce the threats to immersivity.

Here are reported some pictures of the simulation center.





Fig. 6 - The simulation center and the preparation of the scenarios

Debriefing phase

After the scenario the participants joined the rest of the team in the debriefing room. They were greeted with an applause, to make the climate warm and open to discussion. They sat in circle and were facilitated in the debriefing by a psychologist expert in simulation. After the participants described their actions, the observers were invited to add suggestions and comments, facilitating a team reflection on the scenario. This whole phase was conducted using the SPS checklist, enabling the participants and the observers to anchor their comments to specific, observable behaviours. When necessary, the video recording of the simulation was played in the debriefing room, in order to reflect on what has been done, what was remembered, and why.

The outline of the debriefing is listed below:

1. SPS checklist

- a. the participants to the simulation fill in the checklist about themselves
- b. the observers fill in the checklist about their colleagues, divided into two groups, facilitated by a trainer in the discussion of what they observed and what they would have done differently
- c. the participant go back to the debriefing room

2. **Welcome back to the debriefing room:** the participants are greeted with an applause

3. **Defusing:** the facilitator asks the participants "how do you feel?" in order to let them express possible feelings activated during the simulation (e.g. frustration, anger, embarrassment, etc.)

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4. **Analysis:** every participant describes what he had done. If the participants talks about the behaviour of his colleague, the facilitator will refocus the discussion on his own behaviour. Video recordings are used if necessary.
5. **Reflection:** every participant says what he would like to change and what he this was appropriate of his performance. Video recordings are used if necessary.
6. **Observers:** the two groups of observers share what they discussed filling in the SPS checklist.
7. **Discussion:** The facilitator helps the participants and the observers to reflect on specific items. Video recordings are used if necessary.
8. **Take home message:** every participant declares what has learned from this experience.



Fig. 7 - The debriefing

Conclusions

The implementation of the scenarios and the NVC tracking system required many iterations of the process, with several trials and meetings. Many versions of the SPS checklist were produced, progressively refining the tool in terms of usability and reliability. The scenarios were redesigned in order to be realistic, clearly targeting specific learning outcomes, and manageable for the practical setting of the simulation room.

Each scenario had a script with the relevant triggers and the SPS to be addressed. We also wrote a simulation handbook (see annex 3, in Italian) with all the details, the procedures and the description of the scenarios.

The next phase of this research will investigate the relationship between the SPS checklist and the NVC in order to find possible patterns and correlations that could be useful for the debriefing.

References

- Achten, J., & Jeukendrup, A. E. (2003). Heart rate monitoring. *Sports medicine*, 33(7), 517-538.
- Boyle, N.L., Lee, J.D., (2010). Using driving simulators to assess driving safety, *Accident Analysis & Prevention*, 42, 3, 785-787.
- CAA (2004). CAP716 Aviation Maintenance Human Factors. Sussex: CAA Safety Regulation Group.
- Caldwell, J.A., Caldwell, J.L. (2003). *Fatigue in aviation*. Burlington, VT: Ashgate.
- Cook, D.A., Hatala, R., Brydges, R., Zendejas, B. Szostek, J.H., Wang, A.T. (2011). Technology-enhanced simulation for health profession education. *JAMA*, 306, 978-988.
- Cooper, C.L, Dewe, P., O'Driscoll, M. (2001). *Organizational stress; a review and critique of theory, research and applications*. Thouse Oaks, CA: Sage.
- Endsley, M.R. (1995). Toward a theory of situation awareness in dynamic system. *Human Factors*, 37, 32-64.
- Endsley, M.R. (2000). Theoretical underpinnings of situation awareness: a critical review. In M.R. Endsley, D.J. Garland (a cura di), *Situation awareness analysis and measurement*. Mahwah, NJ, LEA.
- Flin, R., Martin, L., Goeters, K., Hoermann, J., Amalberti, R., Valot, C., & Nijhuis, H. (2003). Development of the NOTECHS (Non-Technical Skills) system for assessing pilots' CRM skills. *Human Factors and Aerospace Safety*, 3, 95-117.
- Flin, R., O'Connor, P. and Crichton, M. (2008) *Safety at the Sharp End A Guide to Non-Technical Skills*. Ashgate Publishing Company, Burlington.
- Flin, R., Yule, S., Paterson-Brown, S., Rowley, D., Maran, N. (2006). The non-technical skills for surgeon (NOTSS) System Handbook v1.2, University of Aberdeen, 1-13.
- Gaba DM, Howard SK, Flanagan B, et al. (1998). Assessment of clinical performance during simulated crises using both technical and behavioral ratings. *Anaesthesiology* 89:8-18.
- Hagiwara, M.A., Backlund, P., Söderholm, H.M., Lundberg, L., Lebram, M., & Engström, H. (2016). Measuring participants' immersion in healthcare simulation: the development of an instrument. *Advances in simulation*.
- Hofmann, D., Morgeson, F. (2004). The role of leadership in safety. In J.Barling, M. Frone: *The Psychology of workplace Safety*. Washington: APA Books.
- Kanki, B.G., Palmer, M.T. (1993). Communication and crew resource management. In E.L. Wiener, B.G. Kanki e R.L. Helmreich, *Cockpit resource management*. San Diego: Academic Press.
- Lockley, S. (2004). Effects of reducing interns' weekly work hours on sleep and attentional failures. *New Engle Journal of Medicine*, 351, 1829-1848.
- McGaghie, W. C., Issenberg, S.B., Cohen, M. E. R., Barsuk, J.H., Wayne, D.B. (2011). Does simulation-based medical education with deliberate practice yield better results than 108 traditional clinical

- education? A meta-analytic comparative review of the evidence. *Academic Medicine: Journal of the Association of American Medical Colleges*, 86,706-711.
- Mujber, T.S., Szecsi T., Hashmi M.S.J. (2004). Virtual reality applications in manufacturing process simulation, *Journal of Materials Processing Technology*, 155–156,1834-1838,
- Owen, H. (2016) *Simulation in healthcare education. An extensive history*. New York, Springer.
- Perkovic et al. (2008). The use of integrated maritime simulation for education in real time. Retrieved on <http://web.deu.edu.tr/maritime/imla2008/Papers/50.pdf>
- Rudolph, J. W., Simon, R., Dufresne, R. L., & Raemer, D. B. (2006). There's no such thing as "nonjudgmental" debriefing: a theory and method for debriefing with good judgment. *Simulation in Healthcare*, 1(1), 49-55.
- Salas, E., Rosen, M., Held, J. & Weissmuller, J. (2008). Performance Measurement in Simulation-Based Training: a review of best practices. *Simulation & Gaming*, 40, 3, 328-376.
- Saurin, T. & Wachs, P. & Righi, A.W . & Henriqson, E. (2014). The design of scenario based training from the resilience engineering perspective: a study with grid electricians. *Accident Analysis and prevention*, 68, 30-41.
- Thayer, J. F., Åhs, F., Fredrikson, M., Sollers III, J. J., & Wager, T. D. (2012). A meta-analysis of heart rate variability and neuroimaging studies: implications for heart rate variability as a marker of stress and health. *Neuroscience & Biobehavioral Reviews*, 36(2), 747-756.
- Thomas, M.J.W (2018). *Training and assessing Non-Technical Skills: a practical guide*. Boca Raton, CRC Press.
- Wachs, P., Righi, A., Saurin, T.A., 2012. Identification of non-technical skills from the resilience engineering perspective: a case study of an electricity distributor. *Work*, 41, 3069–3076.
- West, M.A. (2004). *Effective Teamwork. Practical lessons from organisational research* (2th ed.). Leicester: BPS Blackwell.
- Yamao, Saurin, Wachs, Manzolli, Taborda Ribas Tovar, Bório, RIGHI, Henriqson, Ribas, Nara. (2015). Developing resilience skills through scenario-based training: a comparison between physical and virtual scenarios. *Proceedings of the 6th Resilience Engineering Symposium, 2015, Portugal*.
- Yukl, G. (2006). *Leadership in organizations*. 6th ed. Upple saddle river NJ: Pearson-Prentice hall.
- Yukl, G., Van Fleet, D. D. (1992). Theory and research on leadership in organizations. In M. D. Dunnette & L. M. Hough (Eds.), *Handbook of industrial and organizational psychology*. Vol. 3, pp. 147-197. Palo Alto, CA.
- Zhao, D., Lucas (2015) Virtual reality simulation for construction safety promotion. *International Journal of Injury Control and Safety Promotion* 22, 1, 57-67.
- Zhao, D., Lucas, J., Thanet, W (2015). Using virtual environments to support electrical safety awareness in construction. *Proceedings of the 2009 Winter Simulation Conference (WSC) 13-16 Dec. 2009*

ANNEX 1 - SPS Simulation checklist

OBSERVATION CHECKLIST

For each item, check the sentence that best describe the behaviour of your colleague during the simulation.

Colleague _____	Personal Code							
Scenario n° _____	<table border="1" style="display: inline-table; border-collapse: collapse;"> <tr> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> <td style="width: 20px; height: 20px;"></td> </tr> </table>							

Task Management

- | | |
|---|---|
| 1 Tools preparation | <input type="radio"/> Does not prepare the tools before starting the task
<input type="radio"/> Prepares some of the tools in advance, but then, during the task, has to stop to get some other tools
<input type="radio"/> Prepares all the necessary tools and materials |
| 2 Risk Assessment | <input type="radio"/> Starts the activity before the necessary assessments (e.g. check of the metal parts, check of the integrity of the devices, check of all the items present in the scene)
<input type="radio"/> Starts the activity after checking only some of the items
<input type="radio"/> Starts the activity after all the necessary checks (e.g. checks the metal parts, checks the integrity of the devices, checks all the items present in the scene) |
| 3 Personal Protective Equipment (PPE) | <input type="radio"/> Not all the necessary items of the PPE are used
<input type="radio"/> Uses some of the PPE incorrectly (e.g., helmet visor up) or some of the PPE items are not necessary
<input type="radio"/> All the necessary items of the PPE are used |
| 4 Work documentation (e.g., work planning, legal documents, etc.) | <input type="radio"/> Is not read
<input type="radio"/> Is read only after having started the activity
<input type="radio"/> Is read before starting the activity and, if necessary, even after |
| 5 Tools organization | <input type="radio"/> Materials and tools are haphazardly stored, he does not find them because they are left around or hinder the activity
<input type="radio"/> Materials and tools are in place, but sometimes they are not at hand
<input type="radio"/> Materials and tools are stored orderly, effectively and at hand |
| 6 Unexpected events management | <input type="radio"/> Acts like there was no unexpected or anomalous situation (e.g., mismatching data, damages, tamperings or particular characteristics of the environment)
<input type="radio"/> Changes the activity in order to manage the unexpected or anomalous situation
<input type="radio"/> Stops the activity and looks for further information (e.g., talks about it with the colleague or the operation center, seeks for further details, etc.) |

Relationship with the client

(to fill only in case the client is present in the scenario)

- | | |
|-----------------------------|---|
| 7 Information to the client | <input type="radio"/> Does not provide the client any information about the activity
<input type="radio"/> Gives the client information about the activity only if requested or after having started the activity
<input type="radio"/> The client is informed about the activity in advance |
| 8 Client management | <input type="radio"/> Is not able to manage the client (e.g., has a conflict, the client doesn't follow his instructions, is distracted by client's behaviour)
<input type="radio"/> Is able to manage the client, but only after he hindered the activity or had an argument with him
<input type="radio"/> Makes sure that the client does not interfere during the activity (does not disturb, keeps him calm) |

Teamwork

(to fill only in case two or more operators are present in the scenario)

9	Coordination	<input type="radio"/> Works without talking with the colleague about what to do
		<input type="radio"/> Talks with the colleague only after having started the activity
		<input type="radio"/> Starts the activity only after talking with the colleague about what to do
10	Situation assessment	<input type="radio"/> Rarely talks with the colleague and the subject is not related to the current activity
		<input type="radio"/> Discussing about the activity does not bring proposals, says "yes" to everything or does not share his opinions
		<input type="radio"/> Discussing about the activity brings suggestions on how to operate, if he does not agree with the colleague, he explicitly shares his opinion
11	Listening to the colleague	<input type="radio"/> When his colleague is speaking, he does not reply, nods, or he even talks over him
		<input type="radio"/> When his colleague is speaking, sometimes he does not reply or even talks over him
		<input type="radio"/> When his colleague is speaking, he gives him a feedback (explicitly confirms what he has just done or heard what the colleague said)
12	Requests to the colleague	<input type="radio"/> He does not make requests to the colleague
		<input type="radio"/> The requests are generic or ambiguous (e.g. "give me that thing")
		<input type="radio"/> The requests are detailed and complete (e.g. "could you fetch me the screwdriver which is in the toolbox, on that table")
13	Updating the colleague	<input type="radio"/> He does not update his colleague about what he's doing (which step of the activity)
		<input type="radio"/> Updates his colleague only if explicitly requested
		<input type="radio"/> Updates his colleague even if not explicitly requested
14	Management of risky behaviour and violations	<input type="radio"/> His colleague does not have risky behaviours and violations
		<input type="radio"/> Does not point out to his colleague his violations and risky behaviour
		<input type="radio"/> He points out to his colleague his violations and risky behaviour
		<input type="radio"/> Stops his colleague and points out his violations and risky behaviour

ANNEX 2 - SPS Questionnaire

SELF ASSESSMENT QUESTIONNAIRE

Personal Code

1	2	3	4	5	6	7	

Date: ___/___/___

This questionnaire aims at collecting information about safety-related behaviours in your work. Please consider that this is an anonymous questionnaire: therefore we ask you to answer as much honestly as possible, even if you know some actions are not recommended. Our goal is to gather information in order to improve your working conditions, in terms of efficiency, effectiveness, and safety. For this reason, it is very important to obtain an accurate representation of how your job is actually done.

Think about your work in the last month:

How often have you done some of the behaviours listed below?

	Never	Rarely	Sometimes	Often	Always
1 I schedule my work in order to do the most complex tasks when I'm rested	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
2 While I am working I find myself thinking to other things (e.g., the next task to do or things unrelated to the job)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
3 When I notice a wrong behaviour, I stop the colleague and I point it out to him/her	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
4 When I notice an anomaly, I stop working and make an assessment of the situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
5 While I am working, I always have everything I need at hand	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
6 I offer my help to a colleague when she/he is doing a complex task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
7 Before starting a task, my colleagues and I brief each other on "who does what" ("I do this, you do that")	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
8 I happen to get into a heated argument with my colleagues	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
9 Before starting a task, I discuss what to do with my colleague	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
10 I observe and inspect the environment I will operate in to spot and evaluate possible anomalies	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
11 I keep my toolbox tidy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
12 When a colleague is doing a task, if I notice a problem I point it out to him/her	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
13 When dealing with a complex task, I wonder whether I have already faced similar circumstances	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
14 When a colleague offers his/her help, I accept it	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
15 When I notice an anomaly, I discuss about it with my colleague, the team leader, or the unit leader	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
16 I check and assess the integrity of the elements I am going to operate on	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
17 Before starting a task, I organise all the necessary tools and materials	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
18 I read the whole documentation (i.e. work plan, blueprints, etc.) before starting a task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
19 I double check before starting a potentially dangerous action	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
20 I test all the metal parts nearby the operating field with an electrical tester	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21 I wear all the PPE (personal protective equipment) required by the procedure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22 When I am tired or unable to focus I try to have a break	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23 I monitor my colleague while he/she is performing a complex task	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24 Before leaving the offices in the morning, I schedule my working day	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25 While working, I tell my colleague what I am doing in order to keep him/her updated	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
26 I happen to get into a heated argument with a client or a contractor	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27 During complex tasks or critical phases, I make sure if I have understood what I have been told (e.g., I repeat my colleague's request and, before doing it, I let him/her know that I'm going to do it)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28 While performing a task, I stop working and take the stock of the situation	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



MASTER - A multimethod system for the assessment and training of teamwork in simulated scenarios

Contract n° AO2016-07

Partners

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Deliverable 2

- Resume of deliverable 1
- Data analysis method
- Results and comments
- Conclusions

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Resume of deliverable 1

In Deliverable 1 the following topics were addressed:

- *simulation as a training method for safety*: we described the method of simulation as a valid tool to improve safety in complex sociotechnical systems. In particular, we described the non-technical skills (NTS) as part of the broader situated professional skills (SPS)
- *simulation based training for SPS in the electricity domain*: we described how simulation has been adopted as a training method for electricity workers, in particular concerning SPS
- *definition of SPS profile of electrical workers*: we described the development of the SPS questionnaire to assess the capacity of workers to think about safety procedures during their daily working activity
- *development of simulation scenarios*: we described the procedure adopted to develop the scripts of the simulated scenarios, focusing on the SPS addressed by each scenario, and the issue of the standardized client
- *development of non-verbal cues (NVC) tracking system*: we described the setting of the training ground, the remote control room and the complete device list
- *procedure*: we described the scenario's setup, the setting, and the debriefing phase

Data analysis method

The five scenarios have been assessed with three methods:

- Training efficacy evaluation
- subject matter expert (SME) assessment of the performance through video analysis
- NVC assessment through sensors recording physiological data

Training efficacy evaluation

We adopted the Kirkpatrick's Evaluation of Training Model (1959) to assess the efficacy of the training method. The model states there are different outcomes of a training. These outcomes are classified into 4 levels:

- Level 1 - Reaction: to what degree participants react favorably to training
- Level 2 - Learning: to what degree participants acquire intended knowledge, skills or attitudes
- Level 3 - Behaviour: to what degree participants apply what they learned during the training when they are back on the job
- Level 4 - Results: to what degree targeted outcomes occur as a result of the training

Early outcome levels (Reaction, Learning and Behaviour) are mandatory prerequisites to accomplish the long term effects on organizational results (level 4) such as increasing safety, which is usually the real goal of a training. In the present study level 4 outcomes are increasing safety, reducing accidents and, thus, reducing injuries/economic losses. These outcomes can not be seen immediately after the training. Usually it takes a quite long period of time to be able to assess the impact of an intervention on safety. Furthermore, the training should be implemented on all the population of workers and adopted as recurrent training to be more effective. For example, simulation training is mandatory and repeated over

a specific amount of time for pilots in the aviation domain. This approach contributed to heavily reducing accidents (de Winter, Dodou, Mulder, 2012) . The study conducted is a simple pilot study, which involved a small number of people (N = 26) in four different training sessions. None of the participants repeated the training. Therefore it was not possible to assess the organizational outcome for both reason of time (it would have been necessary a much longer period to collect enough data) and statistical power (it would need many more participants to test the efficacy on the number of accidents/incidents).

We limited our evaluation of the efficacy of the training on the first level of Kirkpatrick's model by asking the participants to fill in a questionnaire about their experience during the training, its perceived usefulness and the satisfaction of attending it.

We did not evaluate the second level of Kirkpatrick's model because we did not want to include an evaluation of the competence/performance of the participants in the simulation training. We assume that the efficacy of the simulation method largely depends on creating a safe and non-judgemental place to try, discuss and, even fail.

Furthermore we wanted to evaluate the third level of Kirkpatrick's model (behaviour), but it was not possible to observe the participants on the job after the training. The most suitable way to collect this data was a self-report questionnaire about the application of the Situated Professional Skills of electrical workers. Unfortunately there was no such validated questionnaire. So we decided to begin the validation process of the SPS questionnaire.

Perceived usefulness and satisfaction of participants

An 11-item questionnaire was administered immediately after the end of each training session. The questionnaire aimed to evaluate the experience of the participants. The items measured three main areas (1) quality of the training, (2) Perception and feeling of the participants and (3) perceived usefulness. The questions used in the questionnaire are listed below.

1. Quality of the training
 - a. Do you feel the trainers adopted a non-judgemental and open approach?
 - b. Do you think simulation scenarios were similar to your typical working situation?
 - c. To what extent simulation scenarios were realistic?
2. Perception and feelings of the participants
 - a. How much did you feel committed and inspired by the training?
 - b. How satisfied are you with having attended the training?
 - c. Are you interested in attending other similar training in the future?
3. Perceived usefulness of the training
 - a. Overall, to what extent do you think the training is useful for your work?
 - b. Usefulness of the first part of the training (introduction)
 - c. Usefulness of participating in simulated activities
 - d. Usefulness of watching simulated activities
 - e. Usefulness of discussion after simulated activities (debriefing)

Participants were asked to answer on a 5-point Likert scale (Not at all, A few, Moderately, A lot, Completely).

A one sample t test was performed for each item to evaluate if the mean score was significantly different from the median point of the response scale (3). Table 1 shows all items had an average score statistically higher than 3. Participants considered the training as a valuable event: scenarios were perceived as realistic, participants felt engaged and satisfied and the training was evaluated as useful.

<i>Item</i>	<i>N</i>	<i>Mean</i>	<i>SD</i>	<i>Median</i>	<i>t</i>	<i>df</i>	<i>sig.</i>	<i>d</i>
Non-judgmental approach	26	4.81	0.40	5	22.934	25	< 0.001	4.53
Scenarios are similar to working situations	25	3.72	0.84	4	4.272	24	< 0.001	0.86
Realism of scenarios	26	3.77	0.59	4	6.682	25	< 0.001	1.31
Commitment	26	4.42	0.76	5	9.579	25	< 0.001	1.87
Satisfaction for the training	26	4.35	0.80	5	8.611	25	< 0.001	1.69
Intention to participate to other similar trainings	26	4.00	1.10	4	4.655	25	< 0.001	0.91
Usefulness of the training	26	4.00	0.85	4	6.001	25	< 0.001	1.18
Usefulness of the introduction	26	4.08	0.69	4	7.977	25	< 0.001	1.57
Usefulness of participating in simulated activities	25	4.40	0.87	5	8.083	24	< 0.001	1.61
Usefulness of watching simulated activities	26	4.35	0.75	4	9.211	25	< 0.001	1.80
Usefulness of debriefing	26	4.46	0.76	5	9.799	25	< 0.001	1.91

Table 1 - statistics of the items of the post-training questionnaire

SPS questionnaire

We developed the items of the SPS questionnaire starting from the definition of the SPS profile of electrical workers. The items of the questionnaire were partially derived from the SPS checklist. Other items were newly developed because using a self report questionnaire allows to ask information about the cognitive processes, whereas the checklist used to evaluate the performance must refer only to observable behaviours.

The first version of the questionnaire counted 28 items with a 5-point frequency Likert scale (Never, Rarely, Sometimes, Often, Always). Each item asked how often the participant performed a specific behaviour in his work. Each behaviour referred to the application of one or more SPS of the electrical workers.

An example of the operationalization of the SPS “Risk Assessment” is the item “I check at least twice before performing a potentially dangerous operation”. Annex XX is the complete set of items.

The questionnaire was administered to 188 electrical workers employed by e-distribuzione. Four items did not receive an answer on some response point, thus they were deleted from the questionnaire.

An Exploratory Factor Analysis was conducted on the polychoric correlation matrix of the 24 items.

Different factorial solutions were considered (two, three, four factors). Four factors were considered as the optimal number of factors, based on the RMSEA and TLI. Unfortunately, it was not possible to have a clear loadings pattern; furthermore, it was not possible to identify a theoretical model that could explain how the items clustered together in factors. Thus, this preliminary study could not lead to a definitive form of the questionnaire. The items have to be reviewed to assess their adequacy. A new study has to be conducted with a new sample of participants to test a revised version of the questionnaire.

SME assessment of performance

In order to have a detailed analysis of the behavior of each participant to the simulation, we performed a further assessment with the support of an expert of the electrical operations, provided by e-distribuzione. The assessment consisted in the analysis of each video recording, tracking each behavior and classifying it as compliant, partially compliant or non-compliant.

By compliant we meant that the observed behaviour was completely adherent to the operational rules and procedures for that specific activity. The behaviour was rated as partially compliant when the actions were not completely adherent with the procedures, because some steps in the procedure had been missed or switched. The behaviour was rated as non compliant when the procedure was completely neglected or the workers skipped some safety-critical steps in the procedure.

The analysis of each scenario lasted between 4 and 5 hours, and consisted in the observation step by step of the simulation, and deep discussion with the SME, facilitated by a psychologist. In table 2 we reproduce an example of analysis; the complete set of analyses will be annexed to the deliverable.

Each assessment was composed of:

- Time in the video where the specific behavior was initiated
- Phase of the task
- Description of the activity in the phase (when necessary)
- SME evaluation of the behavior about its compliance with operational procedures
- Explanation of the evaluation
- Description of the behavior (in case of multiple-operator scenarios, this column was replicated for each participant)
- Client action description, when relevant
- Notes in addition to the assessment

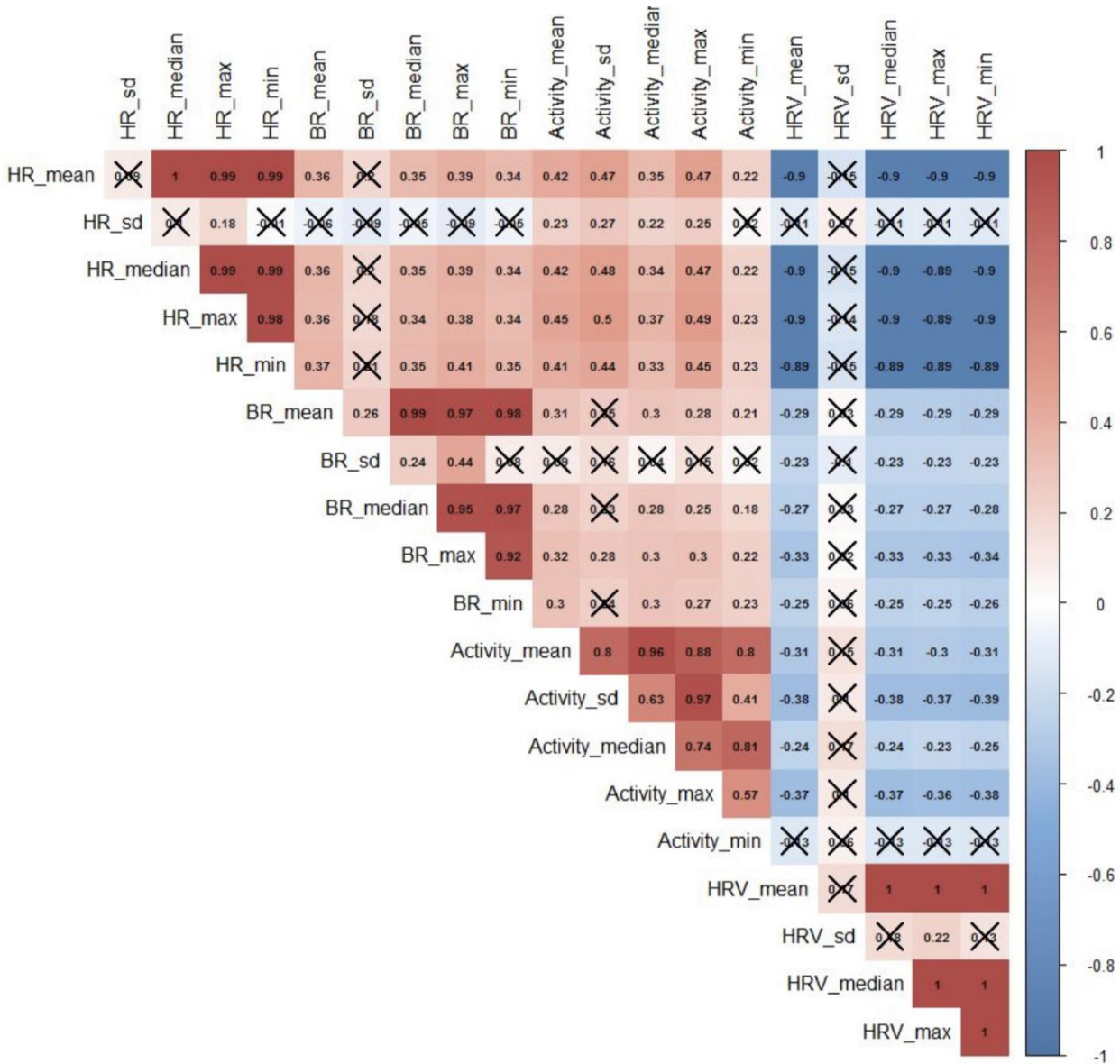
Time	Phase	Description	Evaluation	Evaluation Explanation	1° operator	Client action	Notes
0'00	Analysis	Situation assessment	compliant		RDL analysis		
0'35	Analysis	Situation assessment	compliant		Pushes button on CE		
0'42	Preparation		partially compliant	non-delimited working area	Takes the tools		
1'00	Preparation		partially compliant	shirt out of the pants	Buttons up jacket		
1'36	Preparation		partially compliant		Explains the problem to the client	Start asking question about the intervention; he didn't respect the safety distance (due to the lack of delimitation)	

1'56	Preparation		partially compliant		Asks the client to stay at a safe distance		
2'00	Deprogramming		non-compliant		Starts deprogramming (using the specific device)		
2'14	Deprogramming		non-compliant	forgot to perform the evaluation	1st isolation glove		he takes off the glove after some seconds
2'16	Deprogramming		non-compliant		Asks the client to stay at safe distance		
2'56	Deprogramming		non-compliant	forgot to perform the evaluation	1st isolation glove (again)		
3'24	Deprogramming		non-compliant	forgot to perform the evaluation	Puts on both isolation gloves		
3'28	Deprogramming		non-compliant		lowers the visor		
4'10	Work under electric voltage		non-compliant		starts unscrewing the EC		
5'38	Work under electric voltage		non-compliant	forgot to check the detector	uses the voltage detector		
13'19	Work under electric voltage		non-compliant		End of scenario		

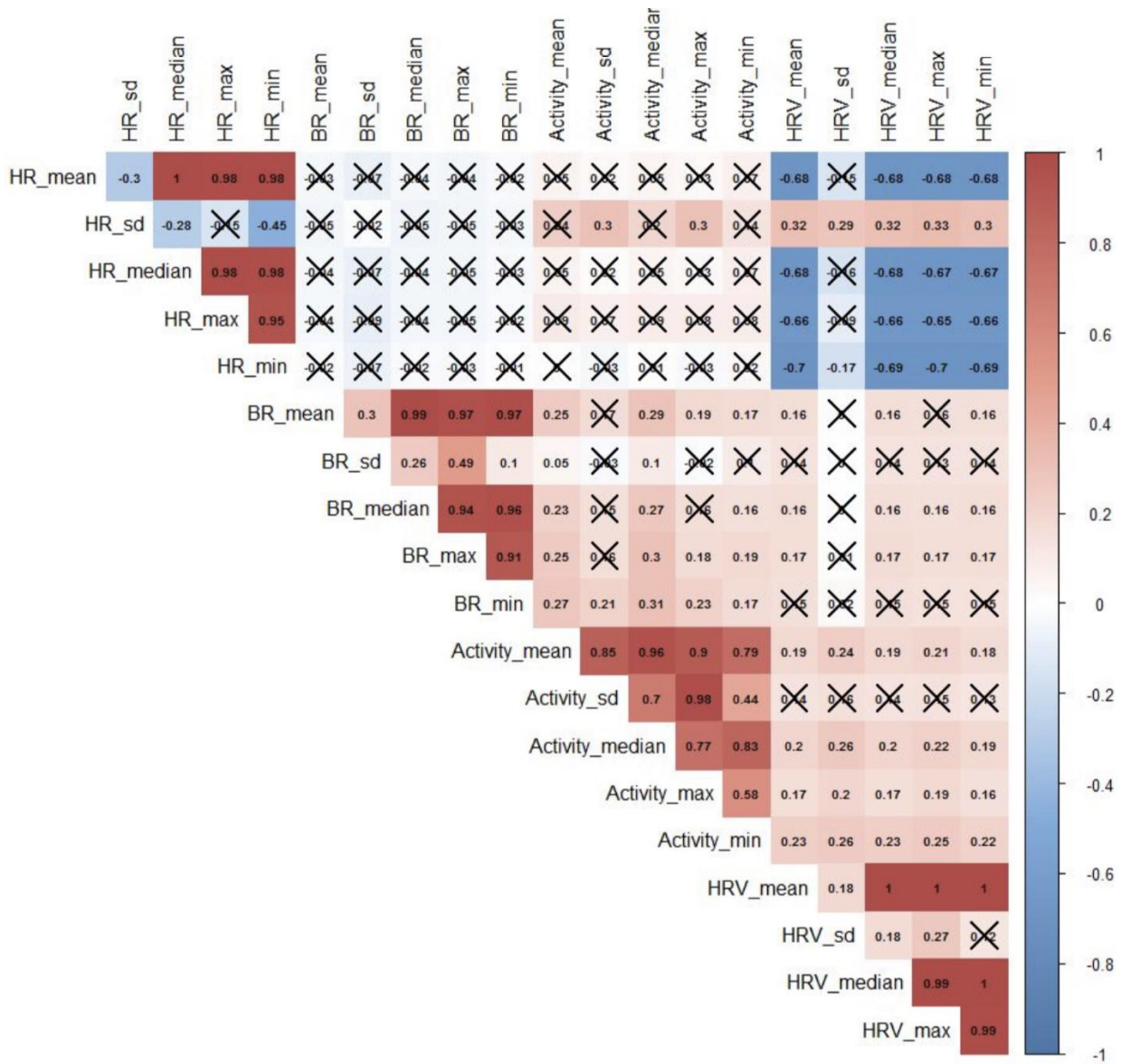
Table 2 – an example of SME's assessment of a scenario

NVC physiological data analysis

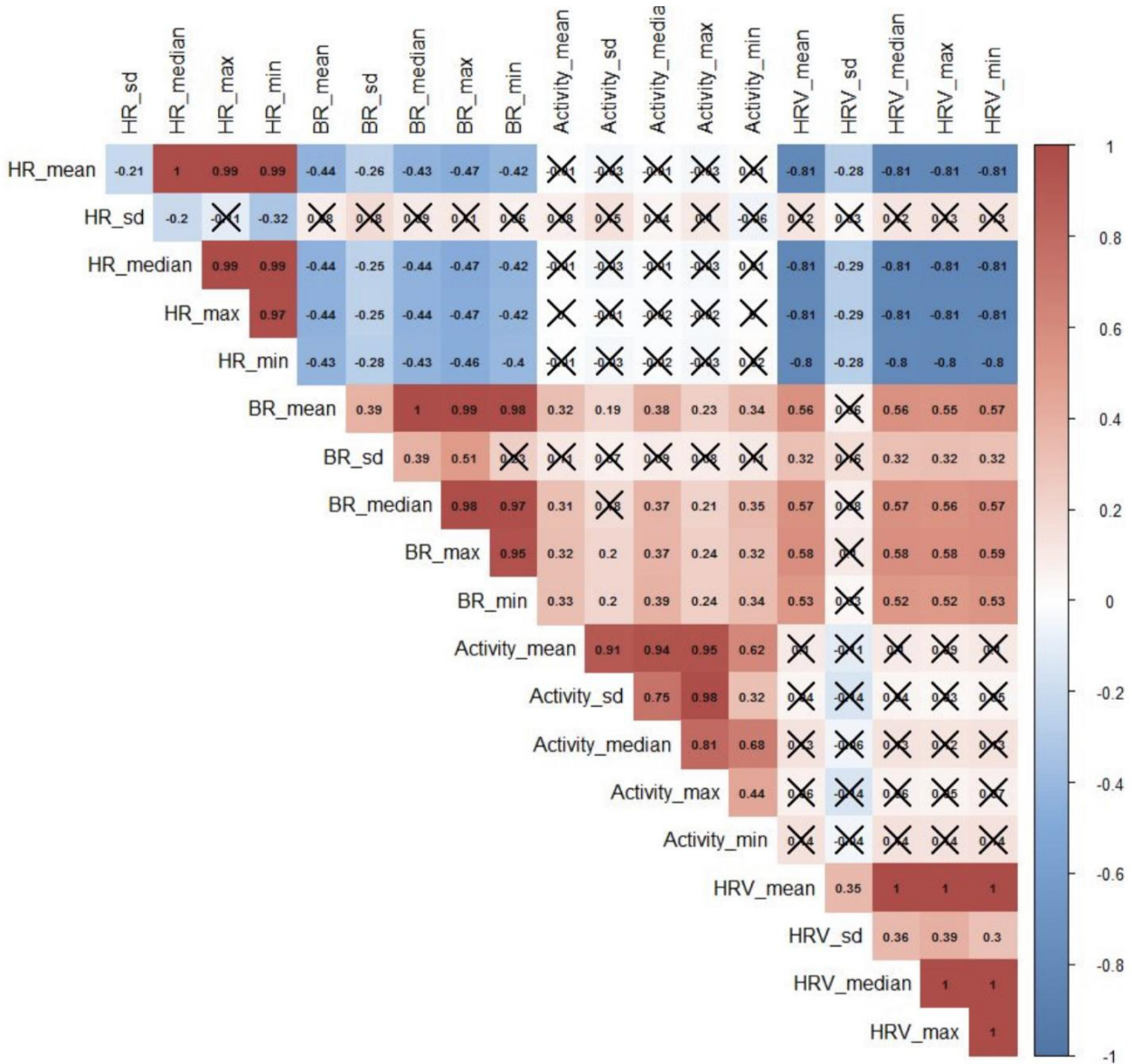
Multiple analyses were conducted in order to analyse how the dependent variables (the NVC physiological data) varied over the different independent variables (the conditions Compliant, Partially Compliant, and Non-Compliant). We described in the first deliverable how the NVC physiological data was acquired and kindly ask the reader to refer to it if needed. The analyses were conducted on the statistical software R. They were of two kinds: correlation analyses and general linear mixed models (GLMM). Correlations are used in research to show how two variables vary in regard to each other. A correlation of value 1 between the variables A and B means that when the variable A is changing in a certain way the variable B changes in exactly the same way. A correlation of value -1 means that it varies in the opposite direction. A correlation of value 0 means that there is no relationship between the two variables. Generalized linear mixed models (GLMM) are used to estimate the value of each NVC physiological data based on the different compliance conditions. GLMMs take advantage of the modelling of random effects to improve precision of the model. For example, in our case, we used the participants (electricians in training) as a random effect since each has a different way to handle the situation and different baseline. This helps measure the true difference between the compliance conditions while taking care of inter-individual differences.



Correlation between NVC physiological data during the compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)

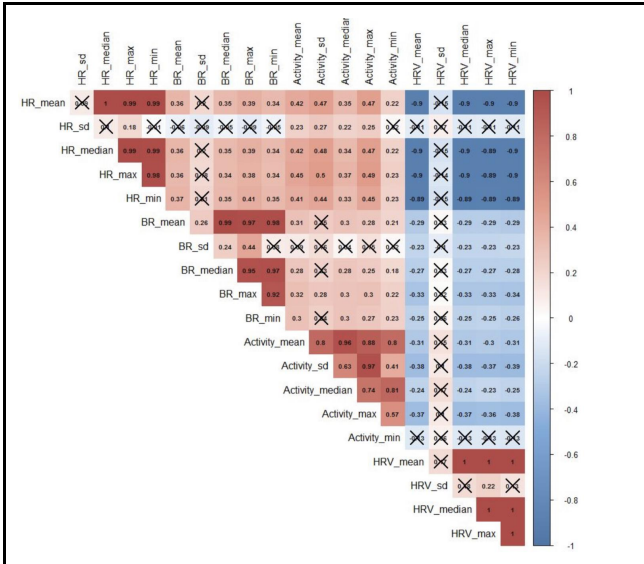


Correlation between NVC physiological data during the partially compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)

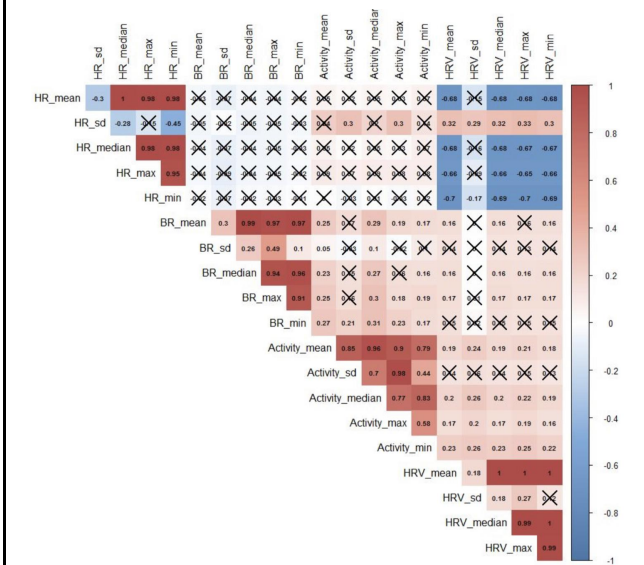


Correlation between NVC physiological data during the non compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)

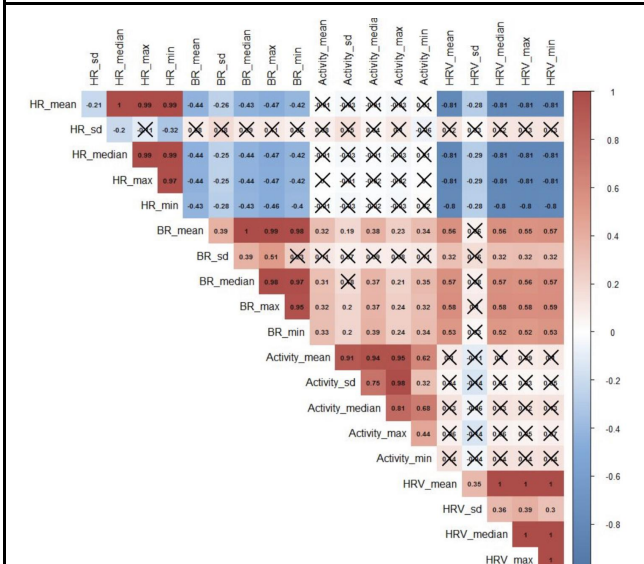
In order to facilitate the comparison we display the patterns of NVC in the three conditions



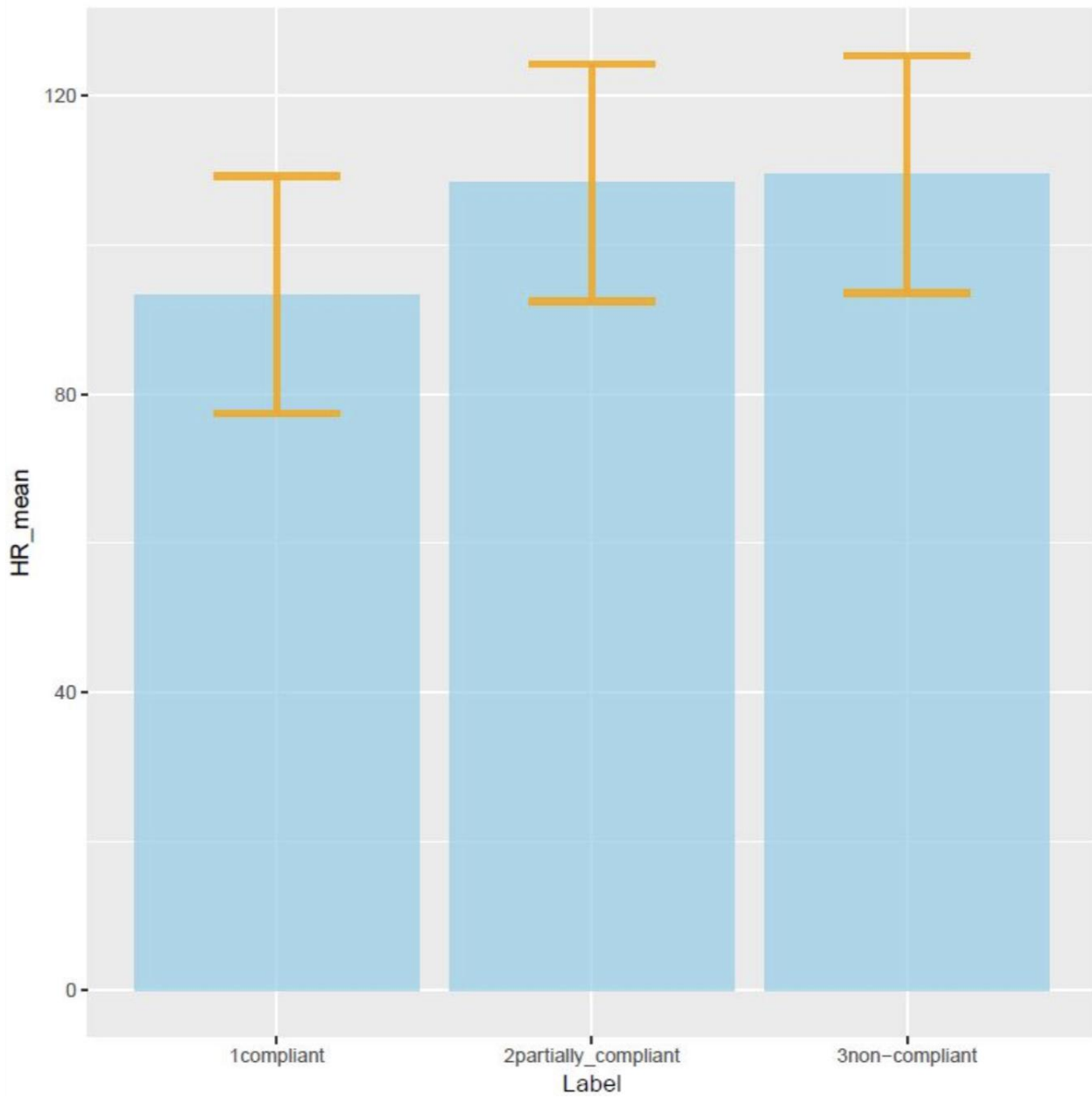
Correlation between NVC physiological data during the compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)



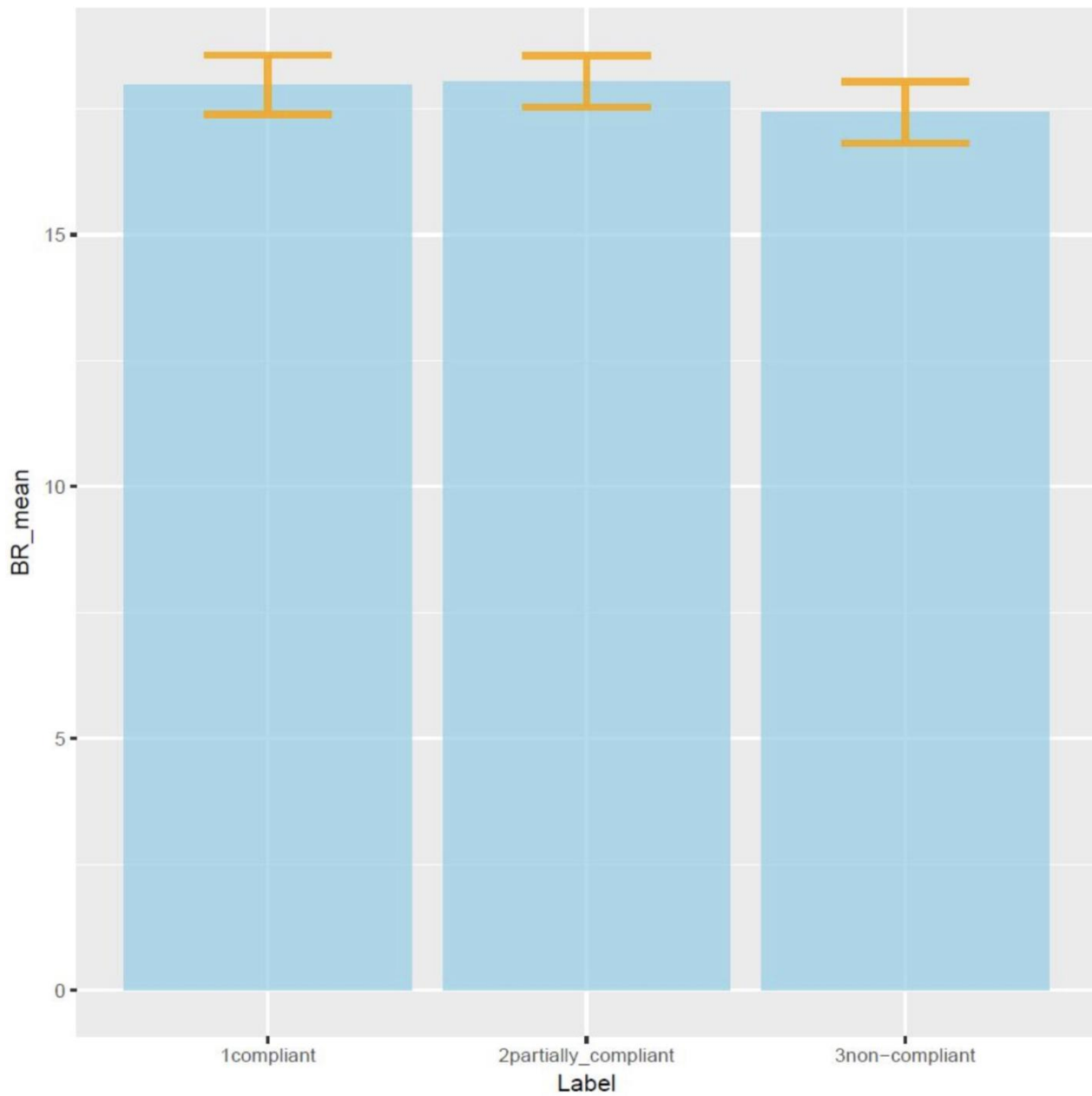
Correlation between NVC physiological data during the partially compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)



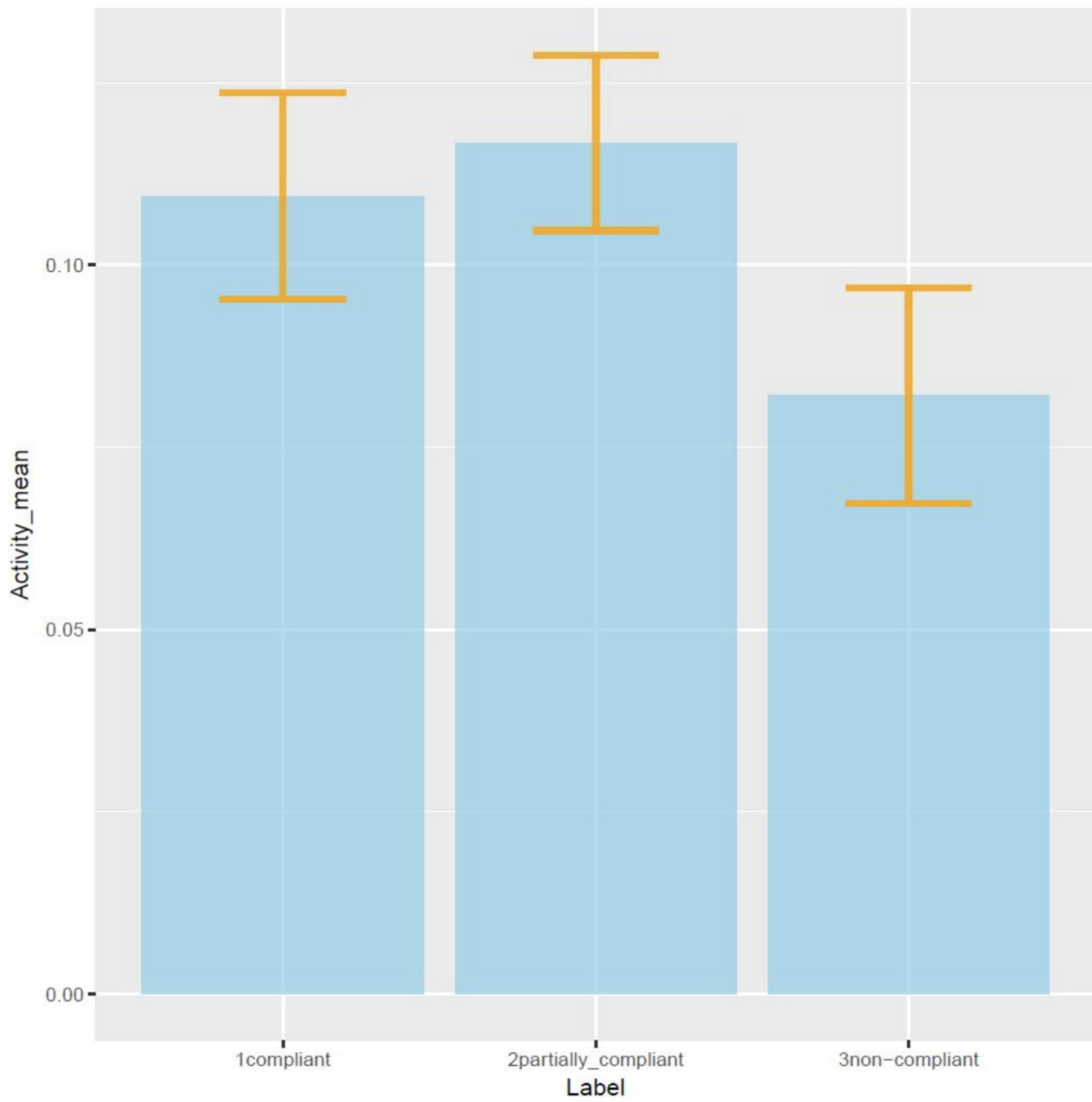
Correlation between NVC physiological data during the non compliant condition (HR = heart rate, BR = breathing rate, HRV = heart rate variability, sd = standard deviation)



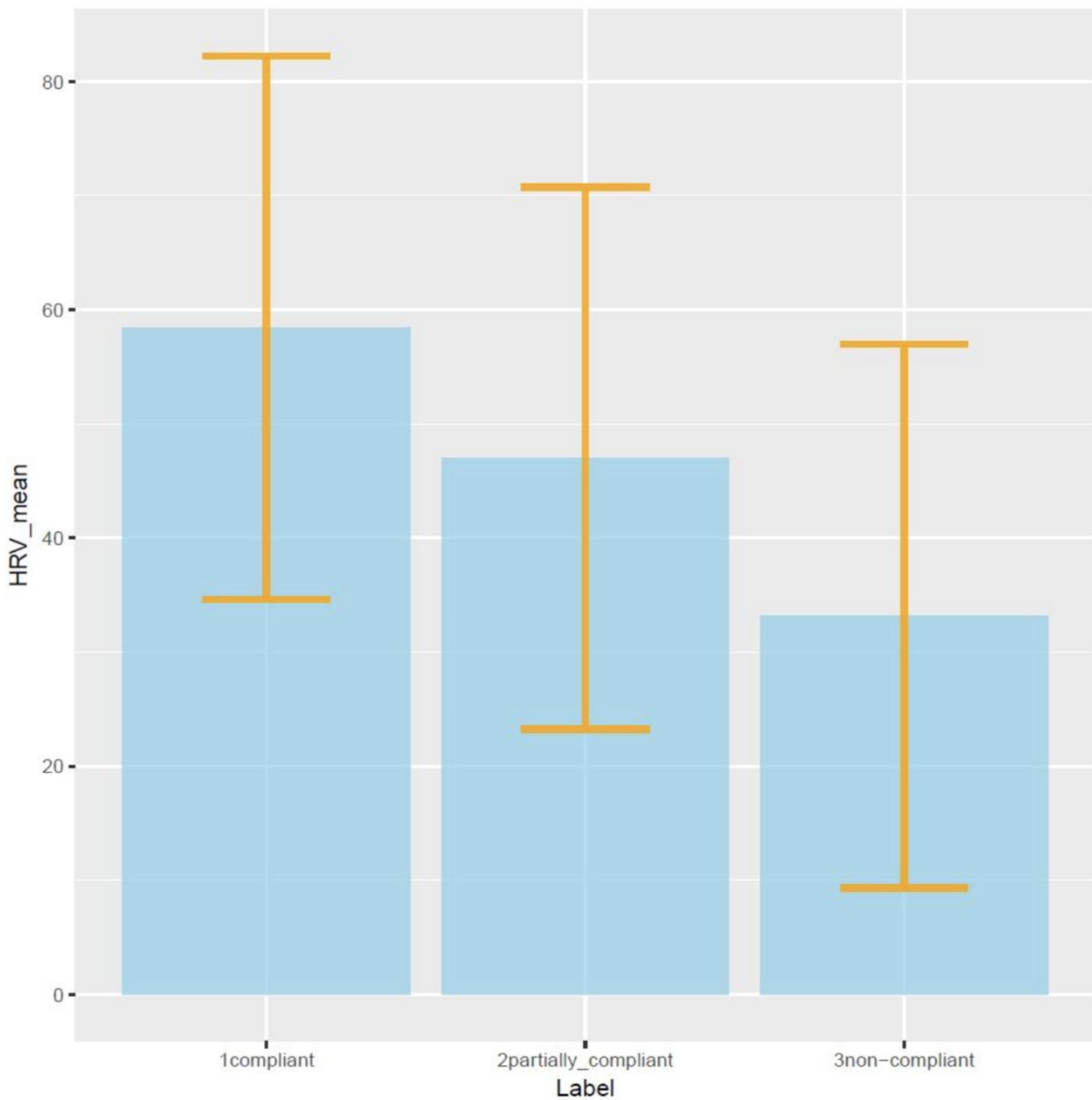
Estimate of heart rate values for all 3 conditions; compliant, partially compliant, and non compliant.



Estimate of breathing rate values for all 3 conditions; compliant, partially compliant, and non compliant.



Estimate of activity values for all 3 conditions; compliant, partially compliant, and non compliant.



Estimate of heart rate variability values for all 3 conditions; compliant, partially compliant, and non compliant.

Comments

The results are potentially very promising, since they show correlation patterns clearly different according to the compliance to procedures. In addition, the physiological data show different trends between compliant and non-compliant behaviors.

Specifically, we comment on the main results.

Breath rate and Heart rate

When the workers are compliant, BR and HR are positively correlated and are decreasing. This result is interesting, since it is a cue suggesting that the workers, in that moment, were in a particularly calm and

mindful state of mind. A decrease in BR, associated with a decrease in HR, seems to be associated with a psychological condition of mindfulness and well being. As suggested by Zaccaro et al. (2018) in their systematic review of the literature about the psychological effects of slow breathing techniques, a decrease in breath rate can “enhance interactions between autonomic, cerebral and psychological flexibility, linking parasympathetic and Central nervous System activities related to both emotional control and well-being” (Zaccaro et al., 2018, 10).

These physiological conditions are commonly considered as a marker of a mindful and relaxed state (May et al., 2016), and it is, in turn, a condition that could enhance cognitive performance (Chiesa, Calati and Serretti, 2011).

The pattern of physiological parameters changes in an interesting way, when the workers are non compliant: BR is low and is negatively correlated with HR. This kind of asynchrony may be correlated with lack of mindfulness and presence of stress. In addition, HR is high also when there is a decrease in the activity, which may be interpreted as a sign of anxiety and stress.

Breath rate and Heart rate variability

When the workers are compliant, HRV is high, BR is low, notwithstanding the increased activity. The activity index during the scenario revealed moments where the workers had to climb the stairs, operate in uncomfortable positions, carry heavy toolboxes, etc. Notwithstanding the increase in the workload, the BR was low when the workers were compliant to procedures. According to literature, high HRV has been correlated to a wide variety of psychophysiological states related to relaxation, emotional regulation, constructive coping with stressors, effective attention allocation (Appelhans & Luecken, 2006). This kind of psychological state is relevant in terms of safety, since it allows the worker to effectively manage his/her cognitive and emotional resources.

When the workers are non compliant, BR is positively correlated with HRV. As reported before, during non-compliant activities, workers’ BR is low and, since it is positively correlated with HRV, we can interpret this result as a sign of stress. As stated by Lo, Wei and Hwang (2020), “the sudden decrease of HRV can be treated as a warning from the body systems [...] and is an objective method to evaluate occupational burnout”.

Conclusions

The aim of this study was to develop a tool for the peer observation of specific behavioural markers for electricians as single operators and as a team during simulated scenarios. In addition, we wanted to add a new sensor-based method for observing behaviours based on non-verbal cues (NVC), like movement in the operational environment.

The basic tenets of the project were:

- training method: simulation is an effective method for competences development in many domains;
- metrics: self and peer assessment tools and a sensor-based system for monitoring team coordination during the simulation;
- key factors: learning by doing, peer-assessment, metacognition and reflection on work activities, visual and concrete representation of teamwork non-verbal dynamics;
- New mechanism for learning: simulation and debriefing, sensor-based system for monitoring team coordination;

- Integration with top-down safety management: simulation is a very effective tool for behaviour change for safety's sake, the training of new procedures, the discussion of "hidden practices", the clarification of attitudes and beliefs.

The stakeholders interested in these results will be practitioners working in electricity distribution belonging to other local units of e-distribuzione or other distribution companies. However, once validated, the method could be easily disseminated to other technical domains (e.g., High Voltage workers, Power plant workers, etc.), or even other work domains (e.g., team of fire-fighters). For the first time in the electric industry, it is possible to explicitly analyse SPS by means of a structured form, based on the specific activities, and, most of all, NVC can be tracked and used for addressing often vague and ill-defined concepts like teamwork and coordination. Moreover, the analysis of NVC will reveal specific patterns of behaviours that are correlated with safe performance and, therefore, could be explicitly addressed during the professional training.

Future developments of this research could aim at developing a new generation of sensor-based systems for monitoring team coordination in both routine and extreme situations, namely a context simultaneously marked by high levels of uncertainty, change and risk. The analysis of social signals and face-to-face communication patterns (e.g., kinesics, proxemics, interpersonal synchronization), could be combined with other sources of information such as survey and performance metrics (e.g., feedback on the SPS, self and peer assessment of performance efficiency, etc.). We argue that these systems could help teams to design interventions aimed at enhancing individual and group performance, especially for coordinating efficiently and ensure their resilient capacity to face risk and overcome perturbations, a critical aspect of extreme situations. By automatically quantifying human behaviour using wearable and non-invasive sensors, we could find relationships between sensor data and team performance and thus identify optimal behaviour patterns that would lead to improved performance.

References

- Appelhans, B. M., & Luecken, L. J. (2006). Heart Rate Variability as an Index of Regulated Emotional Responding. *Review of General Psychology*, 10(3), 229–240. <https://doi.org/10.1037/1089-2680.10.3.229>
- Chiesa, A., Calati, R., and Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clin. Psychol. Rev.* 31, 449–464. doi: 10.1016/j.cpr.2010.11.003
- Kirkpatrick, D. L. (1959). Techniques for evaluating training programs. *Journal of ASTD*, 11, 1–13.
- Lo EV, Wei YH, Hwang BF. (2020). Association between occupational burnout and heart rate variability: A pilot study in a high-tech company in Taiwan. *Medicine (Baltimore)*. Jan;99(2):e18630. doi: 10.1097/MD.00000000000018630.
- May, Ross & Bamber, Mandy & Seibert, Gregory & Sanchez-Gonzalez, & Leonard, & Salisbury, & Fincham, Frank. (2016). Understanding the Physiology of Mindfulness: Aortic Hemodynamics and Heart Rate Variability. *Stress: The International Journal on the Biology of Stress* .. 19. 10.3109/10253890.2016.1146669.
- de Winter, J. C. F., Dodou, D., Mulder, M. (2012) Training Effectiveness of Whole Body Flight Simulator Motion: A Comprehensive Meta-Analysis, *The International Journal of Aviation Psychology*, 22:2, 164-183, DOI: 10.1080/10508414.2012.663247
- Zaccaro, A., Piarulli, A., Laurino, M., Garbella, E., Menicucci, D., Neri, B., & Gemignani, A. (2018). How Breath-Control Can Change Your Life: A Systematic Review on Psycho-Physiological Correlates of Slow Breathing. *Frontiers in human neuroscience*, 12, 353. <https://doi.org/10.3389/fnhum.2018.00353>