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CHAPTER 1

An Introduction to Simulation Training through the Lens of Experience and Activity Analysis

Simon Flandin, Christine Vidal-Gomel, & Raquel Becerril Ortega

1. ADDRESSING MAJOR CONTEMPORARY CHALLENGES FOR VOCATIONAL EDUCATION AND TRAINING THROUGH RESEARCH-INFORMED SIMULATION PRACTICE

In today's world, professionals everywhere are facing rapid and massive technical, social, economic and organizational changes. The domain of vocational education and training has been impacted, and it is now facing new challenges, with the expectation that it will promote approaches based on good/evidence-based practices and respond to growing demands for training in nontechnical/transversal/soft skills (e.g., leadership, communication, situation awareness, stress management) and the imperative of improved performances in the short term. Simulation training is a highly rated means to quickly reach very specific professional learning objectives. But often and overall, simulation training programs seem to struggle to obtain satisfying, long-lasting, and measurable outcomes. It might be assumed that the main reason for this is that, in these programs, the complex human factors of performance tend to disintegrate into skills that are "extracted" from work for organizational purposes. Yet, although human factors are much more "manageable" as skills units, it then becomes very difficult to "reunify" the skills units into a balanced professionalism.

Nevertheless, dividing professionalism into skills units is an increasingly common way of sequencing what needs to be developed and trained for among professionals. The most common division currently distinguishes the technical skills that relate to a specific type of

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work and the nontechnical skills that relate to work in general, a professional field, and even all professions. This division has certain advantages for managing, without which it would not have established itself in the cultures of human resources, management, and education and training. The popularity of the concept of nontechnical skills/soft skills and its now widespread use in work and training organizations is no coincidence either. By providing a conceptual basis and vocabulary, it fits into a much broader trend that has become essential in the contemporary world of work: the specialization of professional functions. Yet this trend can be harmful when it generates two deviations in particular. The first is when nontechnical skills become disarticulated from technical skills, as this makes it difficult for professionals to develop the capacity to intervene in ways that integrate all the components of real work. The second is when skills become artificialized, which occurs when the situational anchoring has been forgotten and the risk is thus high that the skills become meaningless.

The specialization of professional functions can nevertheless be beneficial when it facilitates the pooling of advances produced in professional fields showing strong similarities, such as in the fields covered in this book: healthcare, victim rescue and civil protection. This pooling can contribute to both enhanced performances and improved ways to help professionals achieve better performances, in particular through vocational education and training.

It is important to bear in mind that when skills are considered transversally and are not specific to a type of work, they are difficult to define, operationalize and evaluate, and these are crucial tasks of training design and implementation. Defining training objectives in ways that go beyond the classic domain-related approaches is necessary to draw on the cross-cutting principles for training design. However, definition is difficult because if it is too general, the instructional value remains low, and if it is too specific, the cross-cutting outcomes may not be achieved.

How can contemporary organizational and vocational expectations be met without losing instructional ambition? Given that simulation training is a suitable framework for situated,

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embodied and embedded experimentation, we are convinced that this type of training has much to offer. The research on simulation training to date has nevertheless mainly focused on understanding performance improvements in very compartmented domains of skills or professions. Educational approaches that focus on experience, activity, learning, development, and practice changes do not appear to be sufficiently integrated. A particular problem is that the research evidence often remains domain-related (medical healthcare, fire rescue, civil protection, police intervention, military missions, etc.) and offers simulation trainers very few robust inputs to build programs oriented by cross-cutting principles, even though these professional domains share very similar issues and challenges.

The aim of this book is to present a comprehensive account of the various ways in which the analysis of experience and activity in the context of simulation training (i) helps identify learning affordances and obstacles and provides a detailed description of the learning process and outcomes, (ii) points toward promising design orientations for simulation-based vocational education and training, and (iii) contributes to the overall understanding of practice-based professional learning. Accordingly, the objectives of the book are:

- to describe and discuss the theoretical, methodological, and/or practical issues related to trainees' experiences and activities in simulation training;
- to provide evidence of how the conditions under which lived experience in simulation can foster or hinder learning;
- to identify the conceptual bases and empirical applications and implications of this approach to learning through simulation-based experimentation;
- to contribute to both domain-related and generic orientations for simulation design.

Herein, we thus present the research on various simulation training programs in the domains of healthcare, victim rescue and population protection, involving healthcare workers (5 chapters), firemen (2 chapters), policemen (2 chapters), servicemen (2 chapters), and civil security leaders (1 chapter).

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This opening chapter offers an overview of the conditions under which experience and activity can be fruitful objects for examining what occurs in simulation training, understanding participants' learning and development processes, and deriving robust design principles. It is argued that this approach is particularly useful in the field of simulation training, especially when achieving high standards of operational performance is complicated by critical issues (health, safety, security, protection, etc.) and difficult working environments (dynamic, uncertain, high-risk, etc.). We show that this approach is able to integrate authentic, embodied, and embedded practice experiences with domain-related or cross-cutting learning content. We also provide key concepts that can guide readers in understanding how simulation-enhanced learning and development processes are studied and how the different ways of enabling trainees to construct usable knowledge in verisimilar contexts are derived from these studies. The organization of the book sections and chapters are then presented. In sum, this opening chapter introduces the purpose of the book, explains why the research presented here fills an important knowledge gap, and suggests ways that readers might profitably engage with its contents.

2. THEORETICAL BACKGROUND: A FRANCOPHONE RESEARCH TRADITION IN COGNITIVE ERGONOMICS AND VOCATIONAL EDUCATION AND TRAINING

COGNITIVE ERGONOMICS AND EDUCATIONAL RESEARCH TRADITIONS IN SIMULATION TRAINING

The chapters of this book present studies at the interface of several research traditions, notably cognitive ergonomics and "the ergonomics of activity." Since the 1980s, cognitive ergonomics has focused on the design and improvement of "information technologies" − and more recently on digital resources − by including training in its line of research questions, whereas the ergonomics of activity has been integrated into the sciences of education and training. Much of the research presented here has drawn on these two traditions in particular and sought to contribute to a deeper understanding of simulation as a support for the development of what Chernikova, Heitzmann, Stadler, Holzberger and

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Seidel (2020) call "complex skills": "Critical thinking, problem solving, communication, and collaboration seem to be the most relevant skills[1] that […] should [be acquired], in addition to domain-specific knowledge and skills, to be able to make professional decisions and implement solutions" (op. cit., p. 501). However, unlike these authors, the researchers presented here are not necessarily concerned with initial training or higher education. The studies often focus on a set of professionals from different fields and with different levels of initial training who nevertheless all need to acquire and develop complex skills in order to perform quality work in everyday or more exceptional situations.

Simulation training experienced a real boom in the 20th century with the development of computing resources, computers and digital technology (Rosen, 2013). Cognitive ergonomics, which first emerged in the 1950s, has been interested in simulation since the 1960s, mainly conducting studies in the fields of the military, nuclear power plants and maintenance tasks (Patrick, 1992). In the 1980s, with the spread of new computing tools, simulation training expanded to other industrial and at-risk fields (Norros, 1989). During this period, the research focused on the design and improvement of simulators and simulations for teaching, certification, and training. The validity and reliability of the simulators and simulation situations in comparison to "real work" situations have been widely debated and these issues continue to receive attention (e.g., Drews & Bakdash, 2013; Persson, 2017). At the same time, the research carried out in the sciences of education and training in French-speaking countries since the mid-1990s has tended to focus on the professions of service relations (education and training, healthcare, etc.) in which the interventions relate to another human (particularly with education, development and health objectives). In these professional sectors, the contributions of digital technology are more recent than in industry, and some have touted digital resources for training as the means to achieve major improvements. These arguments recall those that Leplat (1989) and Patrick (1992) pointed to concerning other major contributions that were expected to improve the world of work, when in fact some indeed made real contributions and some were revealed to be limited and/or "naive."

[1] The notion of skill is used here to highlight the characteristics of the tasks to be performed, and this usage is different from that found later in this introduction.

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In the 1990s, the debates began to move in other directions. For example, some focused on the interest and limitations of microworlds designed for *in vitro* experiments (Brehmer & Dorner, 1993). These works underscored the complexity of fidelity: microworlds are artificial situations that are not faithful to "natural" situations, although they retain certain features. Two types of problems were thus raised: that of ecological validity, which can be defined as "the possibility to generalize the conclusion obtained by the study of an artificial situation to a class of natural situation" (Hoc, 2001, p. 284), and that of fidelity. Physical fidelity, or the resemblance to reality (Patrick, 1992), is differentiated from functional fidelity, or "the degree to which a simulator acts like the real equipment" (Grau, Doireau, Poisson, 1998, p. 370), and from "psychological fidelity," which refers to the determination of the psychological dimensions mobilized in the simulated situation that are hypothesized to be equivalent to those at work in a "natural" situation (Baker, Marshall, 1989; Patrick, 1992). Patrick reformulated it in these terms: "The simulation has to represent the task to the trainee in such a way that the psychological or skill requirements of the task are not changed significantly. The trainee should have to deploy the same cognitive activities in performing the simulated task as the actual task" (1992, p. 495). It has thus been well established that physical fidelity is not necessary when the objective of training is the acquisition of procedures or the mastery of tasks for which the cognitive dimensions of the activity are important.

Rogalski (1995) suggested that these problems might be better understood and even resolved by analyzing the tasks to be performed at a cognitive and conceptual level and by modeling the development of professional skills[2] (the KEOPS model). This implies designing simulation situations while retaining or transforming "task functionalities" for a learning and development objective. "The term task functionality refers, on the one hand, to the properties of the deep structure of the task, involving cognitive requirements, and, on the other hand, to the properties of what is often seen as context which are in fact closely tied to the task and have strong effects on operators' behavior when performing a task" (op. cit., p. 127). From this perspective, the model takes into account the situational and

[2] The notion of professional competence used in French, which is often translated by the term "skill" in English, refers to the dimensions of activity mobilized to carry out tasks, to accomplish a mission. Bainbridge and Ruiz Quintanilla (1989) discussed the different meanings of the term skill in English and French cognitive ergonomics.

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organizational characteristics that affect activity and require the development of specific skills by individuals and groups in order to achieve mastery of these situations and obtain the desired results.

SIMULATION TRAINING THROUGH THE LENS OF EXPERIENCE AND ACTIVITY

The debates on validity and fidelity have continued with one example being in the health sector, which tends to favor high-fidelity simulations, thus creating confusion between fidelity and its many components and the "reproduction of the real." In the research world, authors like Persson (2017) and Hamstra, Brydges, Hatala et al. (2014) have suggested dropping the term "fidelity." Persson (op. cit.) pointed out that this term tends to center the debate on technological advances and a resemblance to "real" situations, rather than on the relevance of simulation for learning. Béguin and Pastré (2002) suggested going beyond questions of validity and fidelity in exploring the functions of the simulated situation by putting the focus on trainees' activity and the meanings that the simulation takes on for them. This viewpoint is quite close to that of Rogalski (op. cit.) in that it emphasizes the importance of how trainees interpret a situation, and it may be an important dimension of the skills that need to be acquired.

During this period, the issues surrounding simulations for professional training came to the attention of researchers working within the cognitive ergonomics framework (i) regarding the characterization of expertise and "skills" and the development and learning processes, as in Bainbridge and Ruiz Quintanilla's book (1989) titled "Developing skills with information technology", and (ii) from a training perspective, as in Patrick's (1992) work: "Training: Research and practice." Along the same lines, Hoc, Cacciabue and Hollnagel's book (1995) included a section of four chapters that focused on characterizing expertise and its consequences for training, skills development through simulation, and the limits of operational knowledge acquired on the job and by transmission within a group of peers, as well as how it can be completed through training.

This type of research has intensified in high-risk sectors. As studies have highlighted the importance of collective functioning to ensure the efficiency and safety of work systems,

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this theme has also emerged in research on the use of simulation in training (Salas & Cannon-Bowers, 2001; Salas, Tannenbaum, Kraiger et al., 2012). In the 2000s, training simulations developed beyond these professional environments in response to societal demands, notably in healthcare environments where such rules as “never for the first time on a patient” are unquestioned. They also proliferated because the costs of simulation devices have decreased with technological advances (web 2.0, etc.). Yet, despite this growing body of research, it is regrettable that certain aspects of training simulations, such as the activity of trainers − who are crucial to training effectiveness − have been little explored, with few exceptions (Rogalski, Plat, & Antolin, 2002).

In the 1990s, the education and training sciences of the French-speaking world seized upon a set of theoretical frameworks that mobilized the concept of activity. Fillietaz and Billet (2015) gave a detailed account of this period. Thus, alongside the work in cognitive ergonomics, aspects of which we have noted because of their contributions to simulation training, other orientations developed. This particularly concerned the research carried out from the “ergonomics of activity”[3] perspective, whose researchers have been critical of cognitive psychology, as have “course-of-action” researchers (Durant & Poizat, 2015). These two approaches to “human factors,” for example, can be distinguished from the traditional approaches by the place given to the concept of activity and the systemic point of view that is defended (Daniellou, 2005; Rabardel & Daniellou, 2005; Vidal-Gomel, Boccara, Delgoulet et al., 2019).

Thus, Durand and Poizat (op. cit., p. 223) specified the framework of the "course of action," which defines activity as "what a given actor does as a living, cultural and reflexive unit engaged in a social practice (in this case, work). A here-and-now activity refers to a time point or state in the history of dynamic exchanges between this living unit and its environment.” This approach integrates contributions from Maturana (1988), particularly by taking into account “the living unit as autopoietic,” which means that the unit of analysis is defined as a unit-environment coupling. The definition of coupling within this research

[3] Many authors use the term “French-speaking ergonomists” to designate this line of research. In order to avoid overlooking a large part of our colleagues who contribute and enrich this approach, we prefer the term "ergonomics of activity."

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stream differs markedly from that of other approaches to activity: "Activity is, thus, taken to be the set of ongoing interactions of a living unit and its environment, and it is further assumed that these interactions produce the very structure of this unit and its environment and are in no way the mere response of a predetermined unit reacting to stimuli or adapting to constraints from a world that is itself predetermined. During these interactions, the unit and its environment are in a relationship of co-definition. They define each other. But, this co-definition is asymmetric in that only the living unit specifies what in the environment is meaningful for it (and not the reverse)" (op. cit., p. 226).

Other researchers working within the framework of the ergonomics of activity are closer to the community conducting research based on Russian psychology. The cultural-historical activity theory (CHAT) of Leontiev (1978) and Vygotsky (1934/1978) presents some of the best-known ideas from Russian psychology. Engestrom's model (1987), which was built on an interpretation of CHAT, has been widely disseminated. However, other models, such as the model of Norros (2005, 2014), are less well-known, as are a range of other studies based on Russian psychology (Daniellou & Rabardel, 2005). It is notable that the ergonomics of activity community and the community that has drawn on Russian psychology and its developments continue to interact in events organized regularly for the triennial Congress of the International Ergonomics Association. They are identified under the title "Activity theory for work analysis and design."

In a historical analysis of the development of activity ergonomics, Daniellou (2005) noted how the translation of Leontiev's work into French in 1975 influenced researchers in what was not yet called "the ergonomics of activity." He explained how the concept of activity was incorporated into research that mobilized "psychological analyses of work," replacing the concept of "conduct" that had been used up to that point. In this regard, Daniellou quotes Leplat and Cuny (1977, in Daniellou, op. cit., p. 411): "the central object of psychological analysis is the worker's conduct or in other words, the human operator's conduct. We will sometimes use the word 'activity' as being synonymous with conduct. (...) When analyzing work, we must differentiate the analysis of conduct from the analysis of the requirements or conditions to which this conduct is subjected and to which it replies." This quotation is striking for underlining the reconciliation of the viewpoints of the two communities.

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Daniellou and Rabardel (2005, p. 355) also recalled a set of viewpoints shared by the ergonomics of activity and Russian psychology-based research on the subject of activity, which we recall here very schematically:

● "Activity is finalized. Activity is object-oriented in order to attain one or more goals, which are not always evident, and which the analyst may have trouble identifying.

● The relation between the subject and object is mediated by technical devices, psychological schemes and organization […] These activity mediators are socially and culturally constructed as well as historically situated.

● Activity is always unique. It is specific to given subjects in a given context […].

● Activity bears traces of its past. Activity […] is affected by the subject's life experience and is, thus, constantly revised and reinvested […].

● Activity is not only a relationship between a subject and an object. It is also a relationship with other subjects, who may be physically present or present via instruments and tools, sign systems […].

● The analyst's approach to activity is intrinsic: he/she seeks to understand 'from within' how the subject constructs his/her activity to attain the object, given the resources and constraints at their disposal […].

● Activity is integrational. It is constructed at the crossroads of the subject's motives and goals […] and several determinants, which may be clearly connected to the workstation layout or apparently unrelated (the subject's history, the company's sales policy)."

One of the peculiarities of Francophone ergonomics is precisely its interest in these determinants from a systemic approach, that is, "the point of view that is adopted to jointly take into account a set of dimensions of human activity (biological, psychological, cognitive, social) and that also seeks to highlight a set of determinants of operators' activity, depending on the problem addressed" (Vidal-Gomel et al., 2019, p. 234). Leplat's model (1997), which is shared by many researchers in the ergonomics of activity (Daniellou, 2005), provides a framework for such an analysis. It differentiates:

- the factors that determine activity (characteristics of workers, means of work and tasks);
- the characteristics of the activity in the situations being analyzed;
- the effects (in terms of health or skills development) and results (in terms of productive efficiency);
- last, given the dynamics of the situated action in the short, medium or longer term, the effects that transform the determining factors in a transitory or more lasting way.

This approach has been widely used in the field of professional training, highlighting, for example, (i) the interest of not limiting the scope of activity analysis to the work activities to be trained for; (ii) the need to take into account the work activities of both trainers and trainees and, in some situations, colleagues that are not directly concerned but will have to help new entrants; (iii) the interest of an approach that seeks to understand work situations rather than only the tasks that must be mastered by the end of a training program; and (iv) the importance of subjective engagement at work (Vidal-Gomel et al., op. cit.).

Professional didactics is an heir to both cognitive ergonomics and the ergonomics of activity with regard to understanding work, as well as to a theory of adult cognitive development that considers “conceptualization in action” (Vergnaud, 2009) and seeks to develop a pedagogy of situations for training (Mayen, 2015; Tourmen et al., 2017).

These currents of thought, all based on the concept of activity but sometimes approaching it from different angles, run through this book to varying degrees. We would like to point out that they also share a number of epistemological, theoretical and methodological orientations. We note the following points:

- The actual work (as it is performed in the situation) is differentiated from the work prescribed by those who order its execution orally or via job descriptions;

- The work expected and planned for by the work organization or the workers themselves is different from the actual work;

- Analyzing work cannot be reduced to analyzing the tasks that need to be done. The analysis must take into account the results of the work (results prescribed, expected, and recognized in the company or institution, as well as the various viewpoints on the results)

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and the consequences for individuals, collectives, and the work organization. Also, the analysis takes on its full meaning only with the analysis of activity, which starts from the situated action of an individual or a group and is apprehended through its dynamics as the situation unfolds (action carried out or action prevented);

● The activity is understood to depend jointly on the characteristics of the situation and those of the individual;

● Primacy is given to the analysis of *in vivo* activity and the ecological validity of the results;

● Intervention is an important dimension of the research carried out using these approaches: the research aims to transform work and training environments with the objective of developing the actors.

Among the viewpoints shared by these schools of thought, some relate more specifically to professional training. In particular, it is acknowledged that scientific and technical knowledge is necessary but insufficient to perform work, and it must therefore be supplemented by knowledge about action based on professional experience to ensure optimal preparation for work: “the operator's knowledge comes from basic education, training, and direct experience in working with the system. Through basic education, the operator learns the physical laws underlying the process, the principles of functioning for the components, and the principles that govern the behavior of complex systems. It is, however, only through training and experience that the operator becomes acquainted with how the plant or the process conducts itself in normal and abnormal conditions” (Hoc, Cacciabue & Hollnagel, 1995, p. 13).

When the initial training involves many years devoted to knowledge acquisition (typically higher education), the confrontation with professional situations or simulation situations leads to a restructuring of this knowledge, as well as its articulation with the characteristics of the encountered situations and the knowledge acquired in the course of processing these situations. Thus, Boshuizen and Schmidt (Schmidt, Boshuizen & Hobus, 1988; Boshuizen, Schmidt, Custers & Van de Wiel, 1995; Van de Wiel, Boshuizen & Schmidt, 2000) focused on the initial training of doctors and showed that as doctors acquire experience with the

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situation of dealing with clinical cases, they develop concepts that encapsulate the theoretical knowledge that they have acquired thus far: "*the networks of biomedical knowledge acquired in initial training are included in higher-level clinical concepts*," which means that "*the networks of knowledge about the pathophysiological mechanisms linking the causes and consequences of a disease are 'captured' [i.e., encapsulated] by clinical concepts*" drawn from situated action (Van de Wiel, Boshuizen, & Schmidt, 2000, p. 328). Biomedical knowledge is mobilized when the clinical knowledge is insufficient, and for students with little or no experience this is often the case, while for more experienced physicians it only occurs in rare or complex situations. Pastré (2005) made a similar observation by examining the activity of engineers learning to operate a nuclear power plant on a simulator after high-level scientific and technical training. He hypothesized that during training on simulators, a "*semantics of action*" is constituted in the confrontation with the situation. This semantics articulates the indices present in in the situation and the concepts (scientific and technical or resulting from action in a simulated situation and interactions with peers) that give them meaning and allow for an interpretation of the situation − and ultimately the categorization of situations. Thus, categories of problems and situations are developed in a process he calls "pragmatization," wherein theoretical concepts are transformed.

However, such processes do not take into account the sets of action knowledge necessary for the work, as part of this knowledge remains partly implicit and embedded and includes knowledge of particular cases and different types of experience of dealing with risk and the unforeseen events that punctuate the daily job or constitute exceptional situations − even "crisis situations." In fact, the types of training that interest us here are non-curricular.

APPLICATIONS TO HEALTHCARE, VICTIM RESCUE AND POPULATION PROTECTION

Based on this common grounding, the book chapters focus on the use of simulation in training in several areas of activity, particularly the management of typical, deteriorating or even critical situations in contexts of health and safety. These are areas in which simulation is a necessity because it is impossible and/or unacceptable to learn on the job. It is impossible because of the rarity of crises or disasters and unacceptable because of the risks involved for the professionals and those they serve.

These domains of intervention are all "dynamic environments: It is characteristic of a dynamic system that it may evolve without operator intervention. Thus, even if the operator does not interact with the system, for instance, when he is trying to diagnose or plan, the state of the system may change" (Hoc, Cacciabue & Hollnagel, 1995, p. 4). The situation variables may change at different tempos and their effects may intersect at possibly different moments. The sequences of reasoning required to understand what is happening and to act may thus progress through "several steps."

The characteristics of such work situations have consequences for the skills that need to be acquired: "Working with a dynamic system not only means that time may be limited, but it also means that the mental representation of the system must be continuously updated. The choice of a specific action is based on the operator's understanding of the current state of the system and the expectations of what the action will accomplish. If the understanding is incomplete or incorrect, the actions may fail to achieve their purpose" (op. cit., p. 5).

Among these dynamic work situations, some can immediately be qualified as "crisis management" situations, whereas others drift toward crisis − that is, "an event, in general unexpected, whose consequences may develop with very rapid dynamics, producing significant risks that exceed the pre-existing resources in terms of action procedures" (Rogalski, 2004, p. 531). We might underline that crises have serious consequences. They create "significant and widespread human, material, economic and or environmental losses that exceed the ability of the affected community or society to cope within its own resources […] The development of events following the sudden onset is so rapid that it exceeds the ability to respond […] Events often develop in unexpected directions, thus challenging the readiness and resources of the responding organizations" (Hollnagel, 2012[4]).

Crises thus pose recurring problems, but the shift into crisis cannot be analyzed in the same way across these fields of activity: "disasters are 'normal' in the activity of firefighters, which is not the case for most other systems. Therefore, a variety of resources are already

[4] Unpaged document.

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associated with different types of disasters, the organization of which (actors and resources) has been extensively planned for […] The difference in disaster management by emergency service actors is the relocation of system functions and the overwhelming of pre-existing resources" (Rogalski, 2004, p. 531).

Yet, there are also substantial points in common for these areas of intervention that justify our choice to have brought them together in this book: all these professionals have to deal with risky situations that are not always predictable, despite the planning efforts of their respective professional communities. Thus, in disaster management or at another scale of crisis management, the appropriate response to the situation rarely comes from the application of standardized procedures. They must be at the very least adjusted to the situation, which requires the operators to have a detailed understanding of the situation and the procedures in question. In the field of healthcare with relationships with patients and caregiving, "care" itself cannot be reduced to techniques and procedures that can be applied systematically. Thus, training is not merely a matter of imitation or reproduction. These are, of course, usable training methods, but they must lead to understanding, the construction of meaning, and conceptualization on individual and collective levels. Moreover, these areas are all affected by uncertainty and surprise, which are therefore important characteristics that operators must be prepared for through training.

These are interesting areas for professional training because learning in these contexts is difficult: it is difficult to relate an action that has been carried out to its effects on the situation, especially with the rapidly changes dynamics and entangled variables; it is impossible to go back and learn by repetition; and it is necessary to anticipate (which constitutes one of the difficulties of beginners) in a situation that is uncertain, poses multiple risks, cannot be fully understood, and presents phenomena that may never before been encountered … Indeed, we do not have sufficient scientific models for these contexts, which also underlines the importance of experiential knowledge even though these fields can be very codified, standardized, and procedural, sometimes leaving little room for the actor's experience.

Focusing attention on "fields of activity" can contribute to the construction of knowledge about the characteristics of situations and of the activity in these situations, which can facilitate the identification of relevant training situations. Fields of activity in fact call upon sets of activities, objects and tasks which, at a certain level, can be defined as characteristics, as having common traits (Rabardel & Samurçay, 2004). Thus, we know that the control of dynamic environments, which are characteristic of these situations, requires anticipation, a characteristic of activity. Activity cannot be reduced to this trait, but it encompasses it. Therefore, characterizing fields of activity can help guide the design of simulation situations.

From this perspective, the jobs of firefighters, police officers and healthcare professionals fall within fields of activity that differ in terms of the objectives they pursue, the resources they can access, the organization of the work and value systems.

In these fields, however, although scientific and technical knowledge is necessary, it is insufficient to produce quality work. Knowledge is not always well stabilized and the knowledge that professionals acquire over the course of their experience often remains implicit, poorly understood, and little disseminated and discussed. The contributions of the professional community can therefore be important, although they often need to be discussed and debated to identify their limits. The contributions for training can then be distributed among peers and trainers who may differ in their opinions, particularly because there is rarely a single good response to a situation but rather a set of acceptable solutions, which need to be evaluated according to different types of criteria. In the field of healthcare and crisis management, it may be a question of stabilizing the situation by limiting the consequences of risks according to the resources that are available at time "t." A debriefing can then provide opportunities for debate to examine the chosen solutions and identify their advantages and limitations (Mollo & Nascimento, 2014). Last, in these fields, the experience acquired by the professionals is not always sufficient as they may need to be prepared for new situations: the interest of simulation is precisely that it offers "the possibility of extrapolating and creating a knowledge base starting from bounded experience" (Hoc, Cacciabue & Hollnagel, 1995, p. 13).

In any case, trainees are not considered as having "received" knowledge transmitted by trainers. Simulation situations are designed to give trainees experience, letting them live an experience that can then be analyzed individually and collectively after the fact. This kind

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of a posteriori analysis, removed from the heat of the moment, is an opportunity for professional development.

The training simulations presented in this book also suggest a set of ethical questions: Is it acceptable to put professionals in difficulty in front of their colleagues? How far can they be pushed to confront difficult and stressful situations? What are the consequences for them?

3. SIMULATION TRAINING AS A CONTROLLED SPACE FOR EXPERIMENTATION IN PRACTICE-BASED LEARNING

Simulations grew out of the demand from work organizations to take real activity into account in training situations (Ughetto et al., 2018) by giving individuals the possibility of experiencing or reliving past or current situations (realized or not) and future situations in order to think or rethink more productively about them and better act in them (Bobillier Chaumon et al., 2018). Simulations can be understood as putting activity into perspective, leading to a form of detachment from reality. In this book, simulation is considered a pedagogical and didactic approach to promote experimentation in training that can be configured in different ways, depending on the objectives noted in the research presented in each chapter.

3.1 Simulation, an educational process

The history of simulation as a method of acquiring professional skills (Singh et al., 2013) sheds light on this educational issue. Simulation training drew inspiration from simulations in avionics safety systems and military training, which were then transposed to other professional systems, such as healthcare (Rosen, 2013) or civil security. Simulations in avionics focus on error and action and prevention strategies, with a pedagogical corollary being to "do the experiment without causing damage": without physical damage to self and others, without material damage, and thus without ecological damage. In the military, the simulation tradition aims to make the combat experience more up-close and intimate in

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order to build the military experience needed for success in theaters of operation (Hill & Tolk, 2017). Here, simulations are used to develop and test action protocols and train soldiers to implement them.

Thus, this educational approach places the person "in a situation" *to experiment* in order to learn or question practices. It is based on experimentation with ordinary, complex and even critical situations. Different educational configurations can be used, depending on the knowledge targeted, the type of trainees, the objectives to be achieved (learning, assessment, certification), the technologies available, etc.

On the assumption that experimentation is a continuous elaboration of experience, two cognitive dispositions can be mobilized according to different temporalities. First, regarding the immediacy of action, experimentation is understood as a reworking of the experience *in situ*. This occurs, for example, when a professional in the situation constructs guiding and corrective hypotheses related to action strategies, depending on the context. Second, with regard to long-term experience as a reservoir of available actions inscribed in the biographical or life story, actions are geared toward the success of a project. Experimentation, here understood as a sifting through of experience, is activated to face new situations, thereby contributing to the anticipation and management of future problems.

3.2 Simulation, a didactic approach

The history of simulation also teaches us that its development goes hand in hand with the new possibilities offered by simulators (Rosen, 2013), which are the technical support for simulations (Vadcard, 2019). In the military field, for example, board games were used to develop strategies, then life-size simulations were used to train soldiers (Hill & Tolk, 2017). In the field of medicine, simulation methods can be supported by biological equipment, as in animal experimentation, cadaver use, standardized patients, role plays, etc.; synthetic equipment, like patient or procedural simulators; and electronic equipment, like virtual or augmented reality, 3D environments, and so on (Betz et al., 2014).

Thus, beyond the representativeness and fidelity of the simulation to the situation it represents, the didactic approach is concerned with the design of the training situation.

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Simulators support preconceived simulation situations, most of which are designed from real field situations (military, aviation, clinical cases, etc.). These simulation situations are part of the training system or meet a specific training need. An epistemological vigilance that is specific to this didactic approach consists in identifying the technical constraints that the simulator imposes on the simulation − for example, by limiting the possible actions − and by doing so, it identifies the possibilities of developing new knowledge and skills. This epistemological vigilance also consists in controlling the epistemic network mobilized during the simulation, and not only that of the representation provided by the simulator from the start. Thus, the technical constraints and possibilities of simulations constitute one dimension among others, largely influenced, moreover, by the knowledge and skills brought into play by the trainees and trainers.

Simulation as a didactic approach offers a space for experimentation to elaborate or re-elaborate knowledge. It assumes the elaboration of knowledge from action – on the assumption that this elaboration results in novelty compared to the state of knowledge previously available − and the gradual stabilization of a repertoire of action structures to act effectively and deal with the unforeseen − which presupposes adaptation to the context.

3.3 Simulation, a controlled experimentation space

In this book, simulation is seen as part of a constructivist perspective on learning, heir to major trends in the psychology of learning and development (Piaget, 1947). It has been grouped by some under the term experiential learning (Yardley et al., 2012), which also includes Vygotsky's socioconstructivist perspective. Dewey, for example, argued that experience implies a connection between the action and its consequence for the subject: if the active phase, action, is separated from the passive phase of experience, the reflection carried on about this action, real meaning is destroyed (Dewey, 1934, p. 298). For Piaget (1947), on the other hand, experience is not a primary fact: it must be organized by the subject and presupposes an activity. It is therefore quite different from a system of exogenous associations. Any experience is an experiment in the sense of the subject's organization of a question posed to nature or a situation in which he or she is engaged, which must respond with yes or no. Experimentation is active and cannot be reduced to

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experience in the ordinary sense of everyday experience − that is, simple perceptual contact with events taking place in the external environment.

Simulation, as an educational and didactic process, is constituted as a controlled space for experimentation: experimentation with risks, unforeseen events, or the vagaries of new or known situations, in the aim of elaborating or re-elaborating knowledge. Simulation helps to define the dimensions of a context of anticipation and freedom, so that this context can be assumed by professionals during training.

4. INTRODUCING THE CONTRIBUTIONS TO SIMULATION TRAINING

The contributors to this book have empirically or conceptually analyzed the characteristics and effects of simulation training programs, mainly in the dimensions of the activity deployed and/or the experience lived by the trainees, as explained above. Doing so has enabled them to evaluate the design principles that might fruitfully be generalized and/or to improve their effectiveness for both trainers and trainees. These simulation systems involve one or more categories of professionals in the fields of healthcare, victim rescue or civil protection, and are all finalized by the improvement of performance, defined through a wide spectrum of generic factors (e.g., crisis management) or factors specific to the field of practice (e.g., a technical nursing act).

The contributions bring together:

● Empirical reports based on the study of programs either designed by the researchers or identified in the field as having characteristics of particular interest (innovative goals, original principles, unprecedented attempts, etc.);

● Conceptual reports based on the analysis of current trends and research results in simulation, underlining and criticizing, promoting, and/or deriving new keys for comprehension or new design principles.

This broad scope of analysis has resulted in chapters that describe, analyze, critique and contribute to improving a vast set of simulation practices in the fields of healthcare, victim rescue, and civil protection and that more broadly offer insights into professional learning by practice in simulation training.

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The book is structured into three sections.

4.1 Experience and activity-based conceptualizations of simulation design and outcomes

This first section examines activity as unfolding and experience as meaningful lived episodes during contrasted simulation training situations. It contributes to a deeper understanding of simulation design (objectives, format, tasks, animation, perturbations, facilitation, etc.) and outcomes (from very specific technical gestures to wide and multidimensional dispositions).

4.1.1 Conceptual contributions for the design of activity-led simulation training

The chapters of this subsection (2-3-4) provide insights from empirical and conceptual research about simulation training outcomes and design principles in the domains of healthcare and interprofessional management of civil safety.

Chapter 2, authored by Lucile Vadcard, provides an analysis of simulation-based learning in medicine from a wide range of simulation practices, from mock-ups to virtual reality. In this chapter, she explains what type of experience is provided, depending on the learning objectives, and develops the example of technical gestures in surgery and the Socratic method. Vadcard (i) questions the taken-for-granted quest for realism in simulation, (ii) advocates for strong didactic principles to enable the development of the conceptualization processes needed for technical learning, and (iii) proposes a tool for the analysis and design of promising simulation situations.

In Chapter 3, Simon Flandin also analyzes the conditions under which learning and development can occur through simulation. In his chapter, he describes how civil security leaders develop and reinforce dispositions to act efficiently during crisis management situations through the various features of interprofessional simulation training. Inductively deriving four dimensions for understanding and transforming individual and collective activity, Flandin contributes to the state of knowledge in the fields of collective performance in civil security crisis management and interprofessional simulation design.

This ambition to contribute to a conceptual renewal in the field of simulation training is shared by Zoya Horcik, who explains how a (re-)consideration of the situated cognition approach could prove fruitful for simulation in the medical field. Specifically, she defines three "missed

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appointments" between medical simulation and situated cognition. Chapter 4 thus aims to encourage global reflection on the relationships between theoretical frameworks and design principles by analyzing the links between how learning is conceptualized and how simulation-based training programs are implemented.

4.1.2 Insights from design-based research in simulation training

The chapters of the next subsection (5-6-7) provide design-based research accounts regarding three simulation programs: care gestures in healthcare, patient management in geriatrics, and “mass casualty event” management.

Chapter 5, authored by Christine Vidal-Gomel, addresses the notion of psychological validity by reflecting on the dimensions of work activity that are brought into play in simulation. In this chapter, she analyzes the activity of healthcare professionals in a simulation co-designed by the researcher and a trainer, finalized by the acquisition of a technical gesture: the gesture of "relational-touch." In doing so, Vidal-Gomel contributes to our understanding of the conditions under which simulation promotes the learning of "professional" gestures through practice, here seen (i) as the "transformation of schemas" and (ii) through the lens of the subjective engagement of actors in situation and with their relationship to the profession.

Also in the field of healthcare, the research reported by Raquel Becerril Ortega and colleagues was aimed at developing a virtual simulation training tool for caregivers in geriatrics. Chapter 6 thus describes the whole process of developing this tool, from identifying the training needs (through observations and interviews) to analyzing testers' activity and the "figurations" produced through simulation training. This design-based research account explores innovative avenues for the design of virtual simulation tools addressing difficult healthcare challenges like communicating with patients with Alzheimer's disease or other forms of dementia.

The last chapter in this subsection, from Vincent Boccara, Renauld Delmas, and Françoise Darses, is also part of the design-based research paradigm. In Chapter 7, the authors thus promote a methodological approach they call “ergo-scripting.” This method is based on the argument that the design of learning scenarios must be supported by both ergonomic and didactic analysis of work. Boccara and his colleagues explain how to implement this approach and illustrate it through a concrete example: the design of a virtual training environment to

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train medical leaders as they acquire and develop the skills needed to cope with a mass casualty event (attack, external operation, etc.).

4.2. Empirical lessons from experience and activity-based approaches to simulation training

The second section is devoted to empirical accounts of the activity and experience of professionals through the study of work-as-done in simulation training programs. It informs the field of simulation with original and acute findings on professional engagement and performance in simulation training and offers relevant guidelines for simulation design.

4.2.1 Empirical lessons from the analysis of trainees' activity in simulation training

The chapters of this subsection (8-9-10) present activity studies of professionals’ actions, decisions, communications, interactions, and configurations as they deal with urgent and/or critical events (firemen and policemen).

Chapter 8, authored by Laurie-Anna Dubois, Sylvie Vandestrate, and Agnès Van Daele, presents a study on how firefighters belonging to a "Casualty Extraction Team" manage and learn to manage high risks in a simulated exceptional crisis situation (post-attack crisis). In this chapter, they analyze the activity of both the trainees and trainers in simulation from audio-video recordings. The relevance of the simulation training under study vis-à-vis the skills targeted for acquisition is assessed through the study of transformations in the trainees’ activity. The results contribute to the state of knowledge on preparing for the management of high-risk relief situations.

The second chapter in this subsection also analyzes the activity of firefighters during full-scale simulated rescue situations. Cyril Bossard, Yohann Cardin, Magali Prost, and Gilles Kermarrec studied the construction of collective meaning in intervention during an urban fire simulation. Using subjective video data and resituating interviews, the analysis presented in Chapter 9 allowed them to model six typical collective configurations. This contribution informs both the work of firefighters in this type of intervention and the design of simulation training likely to favor the processes of collective meaning construction, which is a crucial dimension of performance in this type of rescue.

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The methods that use subjective video data and resituating interviews are particularly suited to very fine-grained analysis of the activity of professionals, particularly when they are engaged in very intense interventions. Sophie Le Bellu, Saadi Lahlou, Joshua M. Phelps, and Jan Aandal also used these methods in their documentation of the decision-making processes of police officers during training simulations. In Chapter 10, they propose a method that can be used for both research purposes and training: subjective evidence-based ethnography. This method uses contextualized, constructed, and guided debriefings to make better use of the simulation situation, with benefits to learning and reflexivity for the trainees.

4.2.2 Empirical lessons from the analysis of trainees' lived experience in simulation training

The chapters of this subsection (11-12-13) present fine-grained explorations of the lived experience, concerns, sensemaking and situational dispositions of individual policemen, servicemen, and healthcare workers facing complex and potentially − physically and mentally − intense simulated occupational configurations.

Chapter 11, authored by Rachel Boembeke, Laurane De Carvalho, and Germain Poizat, examines the full-scale simulation training of police officers in intervention techniques and tactics. In this chapter, they document the lived experience of the trainees, particularly (i) their typical concerns, (ii) the nature of their involvement in the situation, and (iii) their methods of knowledge building. The analyses contribute to a better understanding of the optimal conditions for ensuring the effectiveness of high-fidelity simulations and point to the design principles to be favored.

Full-scale high-fidelity simulations offer particularly interesting training opportunities for trainers aiming for a high degree of ecological validity. In the following chapter, Hervé de Bisschop and Serge Leblanc show how simulated situations that are physically and mentally “overly demanding” are able to transform the way in which army officer cadets mobilize, maintain and preserve the resources and capacities needed to fulfill their mission. In Chapter 12, they thus point out the need for disruptive and long-lasting simulations so that the trainees develop “conservatory” arrangements allowing them to “hold on” in the face of critical adversity.

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Critical situations are not always at the heart of professional activity. Elodie Ciccone, Lucie Cuvelier, Anne Bationo-Tillon, and Françoise Decortis were interested in simulation preparation for healthcare professionals who need to communicate with the families of patients, particularly when bad news is announced. In Chapter 13, they examine the role of the sensitive dimensions of experience in the simulation training process. In an original and fertile approach, these authors trace the development of highly specific caring skills that are often reduced in the scientific literature to "relational" or "nontechnical" dimensions.

4.3 Promising avenues for simulation training design and research

The third and last section is a prospective discussion and extension to the preceding chapters. Scholars having broad international expertise in simulation and vocational learning have been invited to react to the preceding chapters, present complementary views, and/or establish the connections between the evidence provided in each chapter and its implications for simulation training design.

In the first chapter, Janine Rogalski considers the book from two perspectives: French-language ergonomics and professional didactics. She first presents her reflections on the studies − particularly French-language − which seem to her to have a structuring role in the field of simulation training for professionals. She then focuses particularly on the examples in the health field to present several promising avenues for future research to both expand our current understanding and enhance effective simulation design.

In the second chapter, Eliana Escudero suggests taking a step back and reflecting both retrospectively and prospectively on the challenges and progress related to the use of simulation for healthcare training. She develops her expert point of view on simulation as a means of improving healthcare performance and patient safety by including an analysis concerning a crisis unprecedented in modern history: the Covid-19 pandemic.