“Work Research Multidisciplinary”

a publication series of Pabst Science Publishers, Lengerich, Germany
edited by Theo Wehner and Tanja Manser

A new publication series is only necessary when psychological topics are sorted newly and individual publications are not collected in the common but in a different systematic way. This is exactly what the publication series “work research multidisciplinary” aims for.

The series’ titel implies that it is not suitable any more to approach the complex research questions related to work research in a singledisciplinary approach. The multidisciplinary approach of the series shall help to show different perspectives of different disciplines (and from within a specific discipline) on a specific topic.

Every volume of the series consists of three parts. The middle part is the core of every volume. It provides the title of the publication and consists of a condensed part of a larger qualification work (mostly a dissertation or habilitation), a research report or also of a concept for future research. This core of the publication shall provide a psychological perspective on the research object. The first part of every volume provides the context for its middle part by presenting several contributions of the “local community” (to which the author of the middle part belongs). The last part of the volume broadens the perspective taken in the middle part to the “scientific community” by including disciplines that approach the research object with different scientific goals and with different research methods. On this basis new areas for inter- and transdisciplinary research can be identified and existing interdisciplinary approaches can be emphasized.

Theo Wehner, Tanja Manser

The use of simulations from different perspectives: a preface

Peter Dieckmann

1. Introduction

This book focuses on the *use of simulation* in acute medical care settings but also beyond that thematic framework. It tries to foster a deeper understanding of what is needed to use simulation in a goal-oriented way. This use requires motivation and competence of those involved: the instructors and researchers, as well as the participants of training sessions, research studies, or assessment-based settings. Understanding how simulation can be used in a goal-oriented way requires finding the right unit of analysis. Looking at simulation scenarios or debriefings alone is not enough. The people involved, and the situation in which they are involved, should be seen as an inseparable unit (Lewin, 1951), and this unit of analysis is the focus of this book. This book will help the reader understand the salient characteristics of simulation as a social practice, and the events that influence (or even determine) the course of actions taken by those involved, no matter which role they take.

The following questions can only be answered, if we understand, in more detail, the social character of simulation: What parts of the simulation are important for a simulation training participant? What does she or he try to avoid, and to achieve, when acting in a simulation? How do the other 'actors' influence how the participant perceives the situation, and how do the technical features of the simulator impact on this perception? How does the perception of the simulation reality compare to clinical reality? What can instructors do to preserve the salient characteristics of the task being simulated?

A second underlying assumption in this book is that simulators and simulations are tools which are used to reach goals: be that continuing professional development; gaining knowledge of the actions people take in research; or judging performance in assessment-oriented settings. Using simulations can add value to all of these areas, and it is this created value that should be the focus of thinking about simulation. The activity of running the simulation can, at least in an occupational setting, only be justified by the value created or at least enabled (e.g. learning on an individual or organisational level) (Curran, 2008). This book is concerned with improving the understanding of the use of simulations as tools to facilitate the creation of value. The tools themselves are described in more detail elsewhere. (Abrahamson, Denson, & Wolf, 1969; Dieckmann & Rall, 2007; Gaba & DeAnda, 1988; Kyle & Murray, 2008; Rall & Gaba, 2005; Riley, 2008).

In an entertainment context the activity of taking part in the simulation maybe the value that is sought (and paid for), consider for example simulation-based rides in amusement parks. We might read novels because we enjoy reading as an activity and the sensations we seek during that activity are our goal. We might on the other hand read text books because we want to master the contents of the book and transform the information it contains into knowledge that we can use. The reading activity is the means by which we reach the goal of increased knowledge in this case. People may take part in a simulation because they like the sensation and the activity as such, and because the instructors put a great deal of effort into making it an enjoyable experience. However, seen from various perspectives such as: the viewpoint of professional development; a learning perspective; and from using simulation for increasing patient safety; this enjoyment is not enough. This book focuses on learning as the goal of simulation use. It shall help simulation instructors in creating learning opportunities for participants and facilitate that the participants actually make use of those learning opportunities. The examples illustrate that to fully understand simulation, the unit of analysis has necessarily to include the person with his or her motives and goals and, at the same time, the situation in which those motives and goals are actualized.

It is important to keep in mind that value can be created in different ways: people learn by reading books; listening to other people; trying out new approaches during practice; thinking about a challenge; and in many more ways (Kolb, 1984). People also learn in different settings that foster certain states of being and experience: the classroom; in the shower; riding a bicycle; in the office; in the simulation setting, etc. Simulation settings can be conceptualised as learning environments. They allow or stimulate certain types of learning, and are less suited for other types. They require substantial resources to be established and maintained. Given limited resources, one should think very carefully about how, when and why simulation is used and, last but not least: for which goals. Some goals might be achieved more easily, or efficiently, using different methods.

Further, simulation-based learning is necessarily a social endeavour; whether direct, as in patient simulation, or mediated as in screen-based simulation. Simulations offer possibilities, and set boundaries at the same time. To make the best use of those possibilites and remain within the boundaries of simulation, formal and informal rules need to be understood and adhered to. These rules, include, but are not limited to, the means by which the simulation represents what is simulated; accepted ways of thinking and discussing within the simulation setting; or the ethical conduct that is required to use this potent method.

Currently the use of simulation is spreading rapidly around the world. Simulation centres are opened; people are trained to use them; an increasing number of target groups and topics are addressed; and the tools are developed further to allow for more precise simulation. The conceptual developments struggle to keep up the pace of the technical developments. However, unclear conceptual foundations might make it difficult to reach the anticipated goals of simulation. Consider, for example, the use of the notion of reality. Often instructors and participants discuss, how 'real' the simulation was. The answer should always be 'really real'; real people used a real simulator, really did spend time with it, and really had an opinion about the sense they saw in this event. What is behind the question about reality of simulation, however, is actually the realism of the simulation scenario (typically not the simulator itself). People compare their view of the simulation to their view of the work setting. When both are similar the perceived realism might be said to be high; otherwise it is low. What criteria they use for the comparison will be discussed in more detail in the ensuing chapters.

A related question that will need clarification for optimising the overall use of simulation is the integration of context into simulation (Johnson, 2004; Rystedt & Lindwall, 2004). The situatedness of simulation is said to be one of its key learning features. However, the definition of context stays fuzzy at times. How much of the specific work context participants work in needs to be replicated in the simulation in order for the participants to meet relevant challenges? One might distinguish between surface context elements (e.g. the exact layout of the workspace in the clinical operating room as opposed to the one in simulation) and more prototypical context factors (e.g. the availability of equipment, not matter how it is placed). How can this context be integrated into the simulation setting? In making these decisions, the salient characteristics of the tasks and the settings in which they are usually carried out, need to be understood, in order to avoid the strive for a superficial replication of clinical situations that might actually miss the salient characteristics of the task. The salient characteristics go beyond the surface characteristics. Currently, often superficial similarities between simulators and scenarios, and actual patients and clinical cases, respectively, are used to justify simulations; being an activity-based more than a value-oriented argument. When reading advertisements for simulation centres, it is striking how much emphasis is placed on the features that make the simulation as close as possible to the clinical setting. It is mentioned that the simulator can simulate a whole variety of cases; that the representation of the patients` vital signs is accurate, and that the 'same' people are involved in a simulation scenario as would be in a clinical case. The underlying idea seems to be that the simulation is better the more it integrates the elements found in the clinical setting. A different approach to implement context factors, would be to identify the salient aspects of a case, such as a challenging or educationally valuable situation, and try to integrate those factors into the simulation. Many context factors that are emphasised in current simulation practice might not be relevant for many learning goals, whilst other factors which are relevant are not fully integrated.

During scenario design, instructors sometimes try to re-create a clinical case, with as much details as possible, no matter whether those details are actually a part of the challenge during the case or salient characteristics of the task. On the other hand, training design might benefit from identifying the underlying structures of challenges and placing them in different contexts to increase learning. In agreement with Kurt Lewin, one might argue that the context always exists in a close interaction between the person and the environment (Lewin, 1951). Neither of which can be understood alone. It needs a person to perceive the context and that person will focus on some parts, leaving others aside; she or he will assign value to perceptions and interpretations. People are always surrounded by a context which shapes how they present themselves, how they experience the situation and also themselves. Defining oneself relies on interaction with others and the surrounding. In this sense it is necessary to closely analyse how participants experience simulations and draw on the context they know from their clinical work setting (Rystedt & Lindwall, 2004).

With the integration of context, the social character of simulation is addressed, as well as the reason why the scientific analysis from the viewpoint of work, and organisational psychology, offers a valuable contribution to medical simulation. Simulation can be used to analyse and optimise complex working areas in medicine and beyond (Manser, 2003); requiring expertise in understanding and re-constituting (Johnson, 2004) the salient characteristics of the tasks that are simulated and the contexts are to be performed under. Simulation settings can be conceptualised as complex working areas themselves. Multidisciplinary teams use different types of technology under organisational circumstances. These circumstances are, at times, challenging for the optimised use of simulation (e.g. when instructors do not get the necessary time for preparing courses and continued professional development). Many topics such as needs analysis; training and curriculum design; development and testing of assessment tools; are addressed by work and organisational studies as well as other disciplines.

To account for the complexity of the endeavour, this book offers different perspectives on the interplay between people, technology, and organisation during simulation settings. Different authors, from various backgrounds, present their views on learning with, and about, simulation. Whilst the first part of the book is aimed, for example, at investigating training effects, and under which circumstances those can be achieved; the second part aims to improve the understanding of how simulation settings can be used to investigate research questions, for example concerning human factors. The selection of the contributions follows the idea of capturing both the physical and social context, as well as what individuals make of this context. The authors in this volume represent (at least parts of) the multi-disciplined background that is found (and needed) in current simulation practice. This book does not capture all the necessary aspects of simulation, but with its composition might offer a several perspectives on simulation that are new to simulation users.

2. The chapters

The chapters follow the basic idea of the series *Multidisciplinary work research* edited by Theo Wehner and Tanja Manser, described in the foreword. The first chapter, in part one, of the book is written by the "local" research group involved in my dissertation that forms the second part of the book. The authors make up the core research group in which the dissertation was conducted. The group has been carrying out research on simulation, with relation to understanding human error and complex work settings, for many years; and has strong links to the authors in the third part of the book. The condensed version of my dissertation, in the middle part of the book, unfolds aspects of the simulation setting in some detail. The text was originally written in German (Dieckmann, 2005) during the years of 2001 and 2005. In the meantime simulation has further developed, and it is difficult to keep up to speed in conceptual terms. For this reason the chapter focuses on centre-based simulation. The data collection and interpretation was based on this simulation modus. Simulation often has either moved out of laboratories or will, soon, do so (Gaba, 2004a, 2004b; Gallagher, Akerman, Castillo, Matadial, & Shekhter, 2008; Rall & Gaba, 2005). Nevertheless, the basic ideas presented in the chapter still hold, or can be adapted, to the mobile use of simulation. In the third part of the book, the authors present their view of aspects of simulation settings that they (and I) think are important. There are several cross-links between the chapters. Here it was important to find people who, on the one hand think along similar lines, but on the other, present a diversity of perspectives. People who look at simulation from different psychological angles; the sociological side, and from engineering; people who are interested in optimising the simulator itself; understanding how human beings make sense of simulations; how instructors can be supported in designing the training session and curriculum; and people who think about the basic assumptions on learning and relate those to the use of simulation.

Peter Dieckmann, Tanja Manser, Marcus Rall and *Theo Wehner* begin by analysing the ecological validity of simulation settings for training and research. Whether the simulation setting captures the important aspects of the setting being simulated, was (and is) a leading question that originally brought me into the field, and is relevant for all authors in one way or the other. After describing concepts, that can be used to compare simulation settings and clinical settings, this chapter describes a strategy to integrate research in the different settings to form a more complete picture during work-related studies. The chapter makes a case for empirically comparing the settings, and taking similarities and differences into account when designing studies as well as collecting and interpreting data. The points are illustrated by describing different simulation-based studies.

Peter Dieckmann unfolds a model of simulation settings that allows for systematising the conceptualisation of simulation use alongside a phase-based model that includes the context of simulation. The simulation setting forms the context for simulation scenarios and debriefings. The simulation centre also provides the context for courses and is integrated into an organisation, which does exist with a social, national and increasingly global context. Concepts are introduced that help describe the features of simulators, the simulation scenarios, as well as the notions of reality and realism. The 'as-if' is described as a key feature of simulation settings. An empirical investigation is presented in which simulation instructors from Germany and Switzerland were interviewed about the goals they pursue when using simulations, what success factors they see in reaching those goals and what barriers. The results of the interview study are discussed by relating them to the theoretical concepts and the model described. Finally, practical hints for optimising the simulation setting are given.

Sven De Weerdt, Johan Hovelynck and *Art Dewulf* build a sound theoretical foundation on which simulation can be justified as an experience-based learning setting. Based on Kolb's learning cycle, learning is described as a fundamental characteristic of human beings. At the same time the authors describe different approaches to learning that might be included in simulation settings. The conceptualisations help in improving our understanding of the interplay of concrete experiences during the scenario, relating them to concrete experiences in the clinical setting, and to reflections during the debriefing. In describing different spheres of learning, and the related roles of the instructors, different learning mechanisms are described; distinguishing individual elements of reflection and elaboration, and social elements of interaction and participation. The chapter then describes the conditions under which the learning potential of simulation settings can be used: creating the safe space needed for learning; guiding participants through their learning process, taking their individual pacing into account; and the extent to which participants can explore new concepts. Thus simulation could be an integrated part of newly defined and framed communities of practice within the medical field.

Klaus Mehl in his chapter takes a closer look at a 'rational use of simulation'. Based on the assumption that simulation might be a laboratory for providing experiences that might be difficult to obtain during operational practice, it is argued that we need a clear picture of routine performance to: a) select scenarios that represent the salient characteristics of the tasks and the challenges which need to be addressed; and b) to formatively assess the performance of participants as well as selecting and sequencing the scenarios and other training elements, for tailoring the simulation to the individual. Based on extensive handling data from flight simulation, this chapter presents an empirical way to describe elements of competence, and to keep track of the individuals' development. Medical simulators function in a different way than the flight simulators. However, the basic principles of formatively assessing persons, describing their training needs and selecting training scenarios based on this assessment are also applicable to the context of patient simulation. Keeping track of the individual competence advances helps the training participants construct their own frame of reference. It can be of great help for instructors, when they select and sequence training events, to have a clear picture of where their participants are, where they have come from, and what their most relevant future training needs are. Having a social frame of reference in which the 'normal' development of the 'average' participant is described, allows for comparing the individual against this average; or differently defined criteria. The continuous comparison of the individual frame of reference, and the social frame of reference, provides the feedback needed to improve learning.

Ericka Johnson addresses different social aspects of simulators and simulations that help in legitimising simulation as relevant for clinical reality, and reconstituting medical practice during simulation. In her chapter different forms of learning are addressed with one focus on the communities of practice approach. The simulation setting can become a place, and time, in which it is possible to develop as a professional, and grow into a position within the medical community; continuous professional development for both medical students and postgraduate personnel. The concepts in this chapter look further than the simulator itself, and extend thinking and perception to the context, the acting persons, the scenario performed, and the following debriefing. In the discussion of practical implications, the chapter helps in using methods to re-constitute medical practice by not only using the physical elements available in the setting but also by being conscious of the interactions between instructors and participants. Legitimacy and relevance are further established via the integration of the simulation event into the larger curriculum. Extending simulation practice beyond the immediate physical aspects helps in using it to its full potential.

Arne Rettedal shares with the reader magical principles, and helps in designing simulations that make it easy to overlook those, technical shortcomings that even modern simulation has. By directing the attention of participants, and using the knowledge of how people perceive and interpret the world, it will be possible to guide the participants to focus on those aspects of the simulation that provide help in perceiving the simulation as realistic - or to those elements that help make the simulation relevant for the learning concept. In his chapter a distinction is made between the external situation and its internal representation by the individual. What counts, after all, is the internal representation of the situation; the physical set-up should be used to get a better estimate of what participants will make of the outer situation.

In summary the chapters shall help in optimising the goal-oriented use of simulation to foster patient safety and quality of care.

3. Acknowledgements

I would like to thank all the authors in this book for their contribution and their patience with me in editing this book. Also thank you to all the participants in the studies that are described in this book. There are many people in the patient simulation community, both in the Society in Europe for Simulation Applied to Medicine (SESAM) and the Society for Simulation in Health Care (SSH) who helped to test and sharpen the concepts presented in this book. The years during which I worked in the Center for Patient Safety and Simulation (TuPASS) in Tuebingen, Germany and the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland and many discussions with Marcus Rall, Theo Wehner, Tanja Manser and Klaus Mehl really shaped my thinking about simulation. The Danish Institute for Medical Simulation (DIMS) at Herlev Hospital, Denmark supported the proof reading of this book and by providing time to finish it. The Pabst Verlag and Armin Vahrenhorst was very helpful in actually turning this book from a dread into a real artefact. Last, not least I would like to thank my partner Nicole Kern for her continued support during the time of writing and editing.

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On the ecological validity of simulation settings for training and research in the medical domain

Peter Dieckmann, Tanja Manser, Marcus Rall & Theo Wehner

Simulators and simulations are increasingly used in many medical domains for training as well as for research purposes. However, different criteria have to be considered when designing effective simulation environments and scenarios for training or for research. Training goals should guide the design of simulation environments used for training. Whereas the possibilities for, and limits of, generalisation of data from simulation settings to the operational setting should guide the design of simulation environments used for research.

„Ecological validity" is a key concept of research in settings other than the actual work environment. So far, little is known about the ecological validity of patient simulators and consequently, about their value as a research setting to study human performance.

Focusing on human performance research, this chapter describes a research strategy integrating simulation and field data in order to improve our understanding of: a) the ecological validity simulation settings; b) human performance in the medical domain; and c) how to optimise the use of simulation in research. This approach combines research about and using simulation environments. We will provide examples of empirical studies conducted using this framework of simulation-based research.

1. Simulation-based training and research in the medical domain

In this chapter, we describe simulation settings for training and research from the viewpoint of ecological validity. This analysis helps in assessing the relevance of simulation for the clinical setting. We introduce the concepts of simulation fidelity and presence to describe certain aspects of similarities between the clinical setting and the simulation setting. Based on these theoretical foundations we outline a research agenda, which relates research in the clinical setting to research in the simulation setting. In a second part of the chapter, we introduce examples of studies illustrating the different connections between (research in) both settings.

1.1 Simulations as training settings

The concepts of simulation and virtual reality (VR) are gaining increasing acceptance in many medical domains for training as well as for research purposes (Rall & Gaba, 2005b). Simulations in different forms are used in education, training and performance assessment of health care professionals from different specialties and at various levels of experience. These include students, interns, residents, and experienced care providers (Dawson, Cotin, Meglan, Shaffer, & Ferrell, 2000; Forrest, Taylor, Postlethwaite, & Aspinall, 2002; Gaba, 2004; Gorman, Meier, & Krummel, 1999; Halamek et al., 2000; Kaufmann & Liu, 2001; Lighthall et al., 2003; Pittini et al., 2002; Reznek, Harter, & Krummel, 2002a). Training goals range from basic technical skills and their integration into more complex clinical procedures, to the training of non-technical skills and aspects of crisis resource management. The spectrum of course formats ranges from simulation-based training targeted at individuals, which is especially useful in training basic clinical skills, (Boulet, McKinley, Whelan, & Hambleton, 2003; Kothari, Kaplan, DeMaria, Broderick, & Merrell, 2002; Taffinder, Sutton, Fishwick, McManus, & Darzi, 1998); to single discipline or multidisciplinary team training including team members from multiple professions that work together in the clinical setting (Gaba, Howard, Fish, Smith, & Sowb, 2001; Howard, Gaba, Fish, Yang, & Sarnquist, 1992; Lighthall, 2004; Marsch, 1998). There is a strong connection between training and organisational development with this mobile „in-situ" use of simulations, and the double role of simulation as an analytic and interventive tool is emphasised (see Mehl in this volume).

In order to be an effective training setting, the simulation environment does not necessarily need to be identical with the clinical work environment. It should provide the learning experiences that meet the learning goals, often involving events that are rare in the clinical work environment. The relevance of the training situation for reaching the learning goal should outweigh striving for maximising the simulation fidelity as such. Some key advantages of simulation scenarios are based on differences between the clinical and the simulation environment (e.g. no negative effect on the patient). The primary design criteria for creating training simulators and for selecting appropriate simulation techniques is the ability to meet specified learning goals and to enable instructors and participants to recognise and use learning opportunities during simulation (Beaubien & Baker, 2004; Nyssen, Larbuisson, Janssens, Pendeville, & Mayne, 2002; Salas, Bowers, & Rhodenizer, 1998). „Similarity" to the clinical work environment or the patient's physiology and anatomy is only one of many factors to be considered in determining the ability to achieve learning goals. Further, „similarity" needs to be considered in more than just the physical dimension (see Dieckmann in this volume). Other factors include, for example, the integration of the simulation-based training into a more comprehensive curriculum, tailored briefings for the use of the simulator and the appropriate conduct of post-scenario debriefings.

1.2 Simulations as research settings

Simulations are increasingly used for human factors research in various domains including medicine. Simulations have been used as research tools to explore various topics relevant to health care such as fatigue (Howard et al., 2003); situation awareness (Gaba, Howard, & Small, 1995); human error (Nyssen, Larbuisson, Janssens, Pendeville, & Mayne, 2000); failure to execute intended actions (Dieckmann, Reddersen, Wehner, & Rall, 2006); the effect of cognitive aids on the treatment of malignant hyperthermia (Harrison, Manser, Howard, & Gaba, 2006); and the design and use of medical devices and displays (Agutter et al., 2003).

As pointed out by Meister:

> „The ideal environment in which to gather data is the operational environment. It may be necessary for various reasons to measure in some environment other than the real world, such as a laboratory or a simulator, but in such cases the conclusions derived from simulator data must be verified in the operational environment" (Meister, 1985, 25).

The operational environments on which we focus in this chapter are clinical acute care settings. Especially in high-risk work environments, human behaviour in uncommon or rare, but critical and potentially hazardous situations cannot be investigated systematically without compromising safety. For different approaches such as routine videotaping see (MacKenzie, Xiao, & Horst, 2004; Weinger, Gonzales, Slagle, & Syeed, 2004). It has been argued that the primary advantage of using simulations for research purposes is that they afford high ecological validity without compromising experimental control (Loomis, Blascovich, & Beall, 1999).

The question as to which criteria have to be met by simulation environments, in order to be effective research settings (i.e. allow a generalisation of data form simulations to the operational setting), is still unanswered. Although there is high face value to using simulations for training and research, some specifics of the simulation setting need to be accounted for to avoid misleading conclusions. A better understanding of potential alterations of experience and behaviour in simulation settings will allow for critically reflecting these effects in the interpretation of results from simulation-based studies. This will help refine and improve psychological theories of human performance in complex work environments.

Simulations become the research object themselves. There are many studies that investigate how, how much, and under which circumstances participants actually learn within simulation courses (Issenberg, McGaghie, Petrusa, Lee Gordon, & Scalese, 2005). Looking at these studies from the point of ecological validity, one might ask whether they suffer from a systematic bias. Many studies rely on a pre- or post-test design with a training intervention in between. The problem we see with this set-up is that of confounding the learning of the actual course contents as compared with learning how to use the simulator. It can be assumed that participants who work with the simulator for one or two days during a training course without much prior simulation experience are still learning the ropes of using the simulator as a tool. This simulation-oriented learning possibly influences or even overshadows the learning of the content of the course. Participants may improve their test scores because they know how to interact with the simulator and have learnt what is expected from them in using it, rather than because they have learnt to improve their performance.

2. Ecological validity of simulation settings

It has been argued that simulation environments could become the future (virtual) laboratories, if the responses in simulation-based and the clinical settings are similar (de Koort, Ijsselsteijn, Kooijman, & Schuurmans, 2003). *Ecological validity* can be the guiding framework for investigating the responses within simulation settings. Ecological validity can be defined as:

> „The extent to which the environment experienced by the subjects in a scientific investigation has the properties it is supposed or assumed to have by the experimenter" (Bronfenbrenner, 1979, p. 516).

As pointed out by (Schmuckler, 2001), a primary function of ecological validity is in its guidance in constructing, conducting, and interpreting research. To evaluate the potential of simulation-based settings for human factors research, empirical studies are needed. These studies should use different methodological approaches to assess the ecological validity of simulation settings by comparing it to the operational setting. In the following we present different concepts that might be used during such empirical studies.

2.1 Concepts of similarity of simulation and operational settings

In different contexts much energy is invested to ensure that the simulation fulfils its own specifications (verification) and that it helps in meeting its goals (validation). Waldstein and colleagues investigated the effects of role-playing stressful situations on heart rate, and compared them with stressful „real life" situations (Waldstein, Neumann, Burns, & Maier, 1998). Ecological validity was investigated in physiological tests as they often involve simulative elements (e.g. cycling in the laboratory) (Jobson, Nevill, George, Jeukendrup, & Passfield, 2008). Neuropsychological tests have also been investigated for their ecological validity (Odhuba, van den Broek, & Johns, 2005). Several concepts have been suggested to describe the similarity of simulation and operational settings. Amongst the most prominent of these are the concepts of fidelity and presence.

In complex domains such as aviation and medicine the issue of *simulation fidelity* has been discussed and studied for a number of years (Hays & Singer, 1989; Rehmann, 1995). As in medicine, one needs to distinguish between the fidelity of the simulator itself (e.g. how much it looks like the simulated system) and the way in which it is used (e.g. the scenario that is run). However, with any kind of vehicle simulator, it is possible to determine whether the simulator reacts like the real vehicle. With patient simulators such a comparison is more difficult because of the natural variation in patient's reactions. „Norm-conform" behaviour of patients is difficult (if not impossible) to describe. In general terms, the concept of fidelity relates to the „environment-to-real-world correspondence" (Bechtel & Marans, 2004, p. 396), with regard to functional characteristics of the simulator as well as to equipment and environmental cues (objective fidelity), and the subjective perception of participants that the simulator realistically reproduces the simulated work environment (perceptual fidelity) (Lane & Alluisi, 1992; Rehmann, 1995).

The subjective aspect of fidelity is similar to the concept of *presence* defined as the „perceptual illusion of non-mediation" (Lombard & Ditton, 1997) in a mediated environment or a „sense of being there" (Slater, Usoh, & Steed, 1994). The concept of presence was first developed in the context of multimedia technologies and „classical" VR systems and has been applied to a broad range of applications including patient simulation (Dieckmann, Manser, & Wehner, 2003). Concerning the measurement of presence, it has been suggested to include not only subjective measures (experiential realism) (Ijsselsteijn, de Ridder, Freeman, & Avons, 2000; van Baren & Ijsselsteijn, 2004), but also objective measures such as physiological and behavioural responses such as posture changes and task performance (behavioural realism) (Freeman, Avons, Meddis, Pearson, & Ijsselsteijn, 2000; Pugnetti, Meehan, & Mendozzi, 2001). For an overview see van Baren & Ijsselsteijn (2004).

2.2 Comparative studies of simulation and operational setting

The high face validity of simulations is a possible reason that there are few studies that systematically compare simulation settings with the clinical environment in the medical domain. Although some studies found no significant differences between the responses to the simulation or operational environment (Ylonen, Lyytinen, Leino, Laeppaluoto, & Kuronen, 1997), most studies from different areas of simulation or VR applications, looking at physiological, experiential and behavioural responses, show mixed results. At times they supported the comparability of results from both settings and at other times did not support it (de Koort et al., 2003; Panerai, Droulez, Kelada, Kemeny, & Bailligand, 2001; Reed & Green, 1999; Rendell & Craik, 2000).

Paisley and colleagues. studied the simulator performance of surgeons focusing on their technical skills (Paisley, Baldwin, & Paterson-Brown, 2001). They found only a low correlation between simulator performance and duration of basic surgical experience with technical skills, assessed by supervising consultants. However, another study focusing on technical skills during laparoscopic surgery found good correlations between simulator performance and validated intraoperative ratings of technical skill (Fried, 1998).

In anaesthesia the assessment of simulation realism has primarily been based on subjective ratings by participants. Results consistently showed that the simulation environment and the scenarios were perceived as highly realistic (Chopra et al., 1994; Devitt, Kurrek, Cohen, & Cleave-Hogg, 2001; Gaba et al., 2001). Some studies used more objective measures such as heart rate variability during neonatal resuscitation in a clinical and a simulation environment (Eich, Müller, Nickut, & A, in press; Murphy et al., 2004). The extent to which groups with more experience in the real task perform better on the simulator than less experienced groups (Reznek, Harter, & Krummel, 2002b) or the occurrence and distribution of unplanned incidents in the simulator (DeAnda & Gaba, 1990) was also used to compare simulation environments with operational settings. In an observational study applying a structured coding system to assess simulation realism, mixed results were found (Hotchkiss, Biddle, & Fal-

Iacaro, 2002). Observers rated the scenarios themselves as highly realistic but raised concerns regarding the short duration of scenarios, the alertness of trainees and a failure to convincingly mirror the operating room culture. Another observational study comparing the performance of experienced anaesthetists in a simulation setting to performance, typically observed in the clinical setting, showed that „only certain aspects of the clinician's skills (e.g. task prioritisation and therapeutic interventions, but not physical diagnoses)" (MacKenzie, Harper, & Xiao, 1996, p. 751) were similar. The authors concluded that simulation performance assessment has distinct limitations due to the limited availability of subtle cues used in clinical decision making.

In summary, the empirical evidence on realism and ecological validity of simulation settings in anaesthesia, as well as in other domains, does not yet allow for a coherent answer to the comparability of both settings. There are some suggestions in favour of ecological validity of simulation settings but also some which question this assumption. It seems as if the same setting is likely to combine ecologically valid elements with those of lesser validity. It further seems as if there is a whole variety of factors influencing the ecological validity of simulation settings above and beyond the characteristics of the tool.

3. Integrating simulation and field data in human performance research

Research on human performance is often conducted in simulation environments (Gaba, 1992; Gaba, 1998; Howard et al., 2003; Manser, Gaba, & Howard, in Press; Weller et al., 2003). The main advantage of simulation environments is that the identical „experimental stimulus" that may be rare in the clinical work environment (e.g. a simulated episode of malignant hyperthermia or different communication barriers) can be presented to multiple study participants under relatively controlled conditions. Here we will discuss potential threats to this control.

Although „performance" is an intuitively meaningful concept, research on human performance in complex work environments usually has to integrate the complementary pieces of information provided by different research approaches; none of which by themselves captures the entire picture (Gaba et al., 1998; Rall & Gaba, 2005a; Salvendy, 2006). Sources of information include retrospective analyses of incident reports (i.e. reconstructive approach to human performance); prospective observation of routine patient care (i.e. naturalistic approach to human performance); prospective observation of the response to simulated events (i.e. quasi-experimental approach to human performance); and objective data from artificial laboratory tasks (i.e. experimental approach to human performance).

Investigating human performance is challenging in all settings. However, many assessments of healthcare professionals' work, especially in critical situations, are only possible in a simulation environment. A research strategy using both clinical and simulation-based research settings is critical in fully developing the strengths, and countering the limitations, associated with either setting. A comparison of data from both settings, allows for cross-validating the results from each and for learning how to run simulations with greater ecologically validity. Finally, from the experiences within simulation settings, there may be reflections and optimisation impulses for the clinical setting.

A special form to combine the two approaches can be seen in mobile „in-situ" training (Gallagher, Akerman, Castillo, Matadial, & Shekhter, 2008; Hohenhaus et al., 2008; LeBlanc, 2008; Miller, Riley, Davis, & Hansen, 2008; Rall & Gaba, 2005b; Rall, Stricker, Reddersen, & Dieckmann, 2005; Rall, Stricker, Reddersen, Zieger, & Dieckmann, 2008); or mock-code trainings (Wood, 1987). Here the simulator is brought into an actual clinical setting and cases relevant to this setting are performed. The setting is highly ecologically valid, although used in a different way during training compared to clinical work. Participants in such training sessions are familiar with the rooms, equipment, procedures and customs, and therefore can act in a similar manner as when treating a patient. In certain forms of mock-code trainings, trained actors are used in such a way that they cannot be identified, and the distinction between the simulation and the clinical setting vanishes. Participants of such mock-code trainings would, for a while, have the impression of actually treating a patient, not a simulated patient. However, as long as the participants identify with the simulation-character of the situation, they engage in a kind of role play, as they are being asked to *learn using simulation* rather than *treat a patient*. Such in-situ trainings would score high in ecological validity if the scenarios reflect the clinical treatment which usually takes place in this setting. One further advantage is that it is possible to use audio-/ video equipment to record the training and then use that recording for debriefing purposes. The (invasive) treatment of the simulator does not have to stop when in reality a real patient could not be treated in this way (unless in a real emergency); think, for example, of defibrillation. A downside is the significant workload involved in organising such a training event. It cannot be taken for granted that the simulation has high ecological validity per se, even if it takes place in the actual clinical setting. It is still a question of thorough needs analysis, scenario design, briefing, conduct and debriefing as to whether the goals of the simulations can be achieved. There is also a question as to whether the participants' experience can be understood or even planned for.