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Resilience skills as emergent phenomena: A study of emergency departments in Brazil and the United States

Priscila Wachs [a], Tarcisio Abreu Saurin [a, *], Angela Weber Righi [a], Robert Lewis Wears [b, c]

[a] DEPROT/UFRGS (Industrial Engineering and Transportation Department, Federal University of Rio Grande do Sul), Av. Osvaldo Aranha, 99, 5. Andar, Porto Alegre, RS, CEP 90035-190, Brazil
[b] University of Florida Health Science Center – Jacksonville, 655 W 8th Street, Jacksonville, FL 32209, USA
[c] Clinical Safety Research Unit, Imperial College London – 10th Floor, QEQM Building, S Wharf Road, Paddington, London W2 1NY, UK

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ABSTRACT

Although the use of resilience skills (RSs) by emergency department (ED) front-line staff is ubiquitous, the nature and origin of these skills tend to be taken for granted. This study investigates the research question "where do RSs come from"? Case studies in two EDs were undertaken in order to answer the research question: one in Brazil and the other in the United States. The case studies adopted the same data collection and analysis procedures, involving interviews, questionnaires, observations, and analysis of documents. A model for describing RSs as emergent phenomena is proposed. The model indicates that RSs arise from interactions between: work constraints, hidden curriculum, gaps in standardized operating procedures, organizational support for resilience, and RSs themselves. An instantiation of the model is illustrated by a critical event identified from the American ED. The model allows the identification of leverage points for influencing the development of RSs, instead of leaving their evolution purely to chance.

1. Introduction

Healthcare systems are widely regarded as primary examples of complexity, due to characteristics such as uncertainty, diversity, tightly-coupled processes, large number of dynamically interacting elements, and resilience (Amalberti, 2013; Hollnagel et al., 2013). This research study is concerned with resilience, which is "the intrinsic ability of a system to adjust its functioning prior to, during, or following changes and disturbances, so that it can sustain required operations under both expected and unexpected conditions" (Hollnagel, 2011, p. XXXVI). In turn, performance adjustment means filling in the gaps of standardized operating procedures (SOPs), whatever their extent and reason (Saurin et al., 2014).

Emergency departments (EDs) have been one of the main healthcare laboratories for investigating resilience (Stephens et al., 2011). This is due to the highly dynamic work environment of EDs, in which following SOPs is far from sufficient – and may sometimes be counterproductive – for providing effective care to patients. The most visible manifestations of resilience in EDs are associated with the performance of front-line employees, often without adequate support from organizational design (Wears and Vincent, 2013). Organizational support would imply system configurations and artifacts that become the instruments by which resilience is brought to bear (Fairbanks et al., 2014).

One of the means for providing organizational support is to influence the development of the resilient skills (RSs) of the workforce. These are the "skills of any type necessary to adjust performance, in order to maintain safe and efficient operations during both expected and unexpected situations" (Saurin et al., 2014). In turn, a skill is a goal-oriented, well-organized behavior performed with economy of effort (Proctor and Dutta, 1995).

Other terms have been used in the human factors literature to refer to similar concepts – e.g. improvisations (Trotter et al., 2013), tacit skills (Ambrosini and Bowman, 2001), and non-technical skills, NTS (Flin et al., 2008). Overall, commonalities between these concepts are the use of the individual or team as the unit of analysis, and their concern with performance for dealing with unexpected situations.

We opted for RSs mostly because we approach this concept from

* Corresponding author.
E-mail addresses: priscilawachs@ig.com.br (P. Wachs), saurin@ufrgs.br (T.A. Saurin), angelawrighi@yahoo.com.br (A.W. Righi), wears@ufl.edu, r.wears@imperial.ac.uk (R.L. Wears).

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the perspective of resilience engineering (RE), which is concerned with the observation, analysis, and design of resilient systems (Nemeth and Herrera, 2015). RE stresses the creation of organizational conditions that support resilient performance at the sharp end (Bergström et al., 2015). This is a distinctive commitment of RE, and therefore of RSs, in relation to the previously mentioned similar concepts. While RE does not deny that personal qualities matter (Reason, 2008), it counters the tendency to over-valuing "heroic" behaviors of practitioners (Schulman, 1996) and relying excessively on elite performers (Ericsson et al., 2006).

Regardless of the ubiquitous presence of RSs in EDs, little is known on how they arise. RSs and resilience in general are often regarded as emergent phenomena (Bracco et al., 2008; Nemeth et al., 2011; Day, 2005). This conveys the idea that interactions between agents "set the stage" for resilient performance, which cannot be developed and deployed in a fully controlled manner. While it is intuitive that RSs arise from interactions, there is no framework for tracking the factors intervening in these interactions neither for analyzing how these can be influenced. Indeed, while observations of resilience in healthcare have been frequently reported in literature, these have not yet revealed where resilience comes from, neither what supports or degrades it (Nemeth and Herrera, 2015). Also, there is a need for providing empirical evidence to support the notion that RSs are emergent.

This research deals with the gap aforementioned ("where do RSs come from?") through the investigation of RSs in two EDs: one in Brazil, and the other in the United States. While both EDs share similar characteristics, they also have marked contextual differences, thus offering a rich empirical basis for investigating the origins and role of context on RSs. A model of the interactions leading to RSs is offered as an alternative for answering the research question.

2. Resilience in emergency departments

Healthcare and EDs in particular has been a domain of interest for RE. Wears et al. (2006) described how the resilient capacity of an ED was exceeded due to overcrowding. Stephens et al. (2011) reported how resilient performance relied on interactions with other areas of the hospital. Perry et al. (2006) described how shared decision-making, involving professionals who had never worked together, was crucial for the successful treatment of a pregnant patient in an ED. Anders et al. (2006) assessed five characteristics of resilience in the trauma area of an ED: buffering capacity, flexibility, margin, tolerance, and cross-scale interactions. Sujan et al. (2015) investigated how the study of everyday clinical work offered insights into patient safety in handover activities carried out in an ED. Anderson et al. (2013) proposed a framework for managing the four abilities of resilient organizations in an ED: anticipating, monitoring, responding, and learning. Wears and Perry (2008) explored the use of system dynamics for modeling resilience and brittleness in overcrowded EDs.

Overall, previous studies on resilience in EDs had a stronger focus on the observation of resilience, placing less emphasis on analysis and design. Furthermore, while a number of contextual factors that trigger resilience may be identified from these studies, this information is mostly a by-product rather than the main research objective.

3. Emergence

Emergence is widely regarded as a defining characteristic of complexity (Dekker, 2011). Emergent phenomena arise from the interactions among several variables, and they have unique properties that are not found in any of the interacting variables (Cilliers, 1998). Such phenomena may be either desired or undesired (Buchli and Santini, 2005), and while they cannot be fully controlled they can be influenced to some extent.

A metaphor commonly used to explain emergence is that the whole is more than the sum of the parts – less emphasized, but also noticed by Cilliers (1998) is the fact that emergence can imply the whole is less than the sum of the parts. Indeed, Heylighen et al. (2007) note that not only is the behavior of the whole influenced by the properties of its parts, but the behavior of the parts is to some degree constrained by the properties of the whole. Thus, given its nature, the investigation of emergence must stress the interactions between parts, rather than the parts themselves – of course, knowing the parts is important but not the key for understanding (Dekker, 2011). For the purposes of this study, investigating RSs as emergent phenomena means that we are concerned with how interactions between the elements forming a sociotechnical system give rise to RSs.

4. Research method

4.1. Research strategy

In order to investigate RSs, two case studies were carried out. This research strategy was chosen mostly because case studies (Flyvbjerg, 2011) are a means for developing context-dependent knowledge, which is a key for accelerating the learning process of novices. Premises of case study design were followed in order to increase the credibility of the findings, as follows: (i) identification of literature gap; (ii) development of data collection protocols (Eisenhardt and Graebner, 2007); (iii) intentional selection of cases (Flyvbjerg, 2006); (iv) delimitation of the boundaries of the case Flyvbjerg (2011); (v) triangulation of data and data sources (Noor, 2008); (vi) development of a database, allowing traceability and reinterpretation of data when necessary (Flybjerg, 2011); and (vii) use of visual representations to illustrate the contributions of the study (Eisenhardt and Graebner, 2007).

The case studies were undertaken in the EDs of two University hospitals: one in Brazil and the other in the United States. The research project was approved by the ethical committees of both hospitals. The main reasons for selecting these cases were: (i) they had been objects of recent RE studies (Righi and Saurin, 2015; Righi et al. 2016; Wears et al., 2007; Wears and Perry, 2008), which made it easier access for data collection and facilitated acclimation of the researchers; (ii) they were EDs of reference in their respective regions, which suggested staff was highly qualified; and (iii) their academic nature, which could encourage critical thinking.

The studies focused on the work of the three categories of professionals mostly involved in patient care, namely physicians, nurses, and nurse technicians. The focus on front-line staff was mostly due to immediate impact of their actions on patient safety and ED performance, in addition to the ease of observation.

A premise for the field study was that the unit of analysis should be the joint cognitive system (JCS) formed by the interactions between the individual professional and their social and material environment. According to Hollnagel and Woods (2005), a JCS is a co-agency between people and technology that uses the knowledge about itself and the environment to plan and modify its actions in order to achieve a goal. A JCS not only uses what is inside people's minds, but also representations distributed along the social and material structures (Hollan et al., 2000). Therefore, data collection was not only concerned with the identification of RSs

themselves, but also with the context in which they were deployed.

4.2. Data collection

Similar data collection procedures were adopted in both EDs, thus providing internal consistency for the study and allowing comparisons between both environments. Considering the intention of accounting for the context of RSs, sources of data involved direct observations, interviews, analysis of documents, and meetings (Table 1).

Observations were carried out in varying times of the day and days of the week, in order to account for the variability of real work. Researchers used a diary to record both observed facts and insights from the observations. These observations contributed to acclimation of the researchers, understanding of work flows, and as a means for making sense of information from other data sources. Observing training sessions was also useful since it permitted realizing how professionals reacted to challenging situations included in simulations (e.g. simulations of handling mass casualties in the American ED).

We used two types of interviews: critical decision method (CDM) and questerview. The CDM interviews (Crandall et al., 2006) started with the record of information about the profile of the interviewee (e.g. age, experience), followed by a request for an overview of the interviewee's tasks and then it moved on to the four stages of CDM: identification of a challenging event experienced by the interviewee, development of a timeline, deepening, and "what if" queries. As a drawback, some of the interviewees had difficult to recall discrete events from beginning to end; in these cases the CDM was abbreviated and two or more shorter stories were discussed in order to compensate for gaps in the reports. Crandall et al. (2006, p.84) mention that this may happen when people work under stressful conditions and handle very high workloads.

The questerview (Adamson et al., 2004) involved asking subjects to complete a survey exploring complexity characteristics of the EDs that could influence RSs, and then going over their responses asking them to explain and deepen their answers. Both the CDM interviews and dialogs arising from the survey were tape-recorded and then fully transcribed. While this paper focuses on the qualitative data arising from the questerview, a detailed quantitative analysis of the survey is presented by Righi and Saurin (2015) – Brazilian ED, and Righi et al. (2016) – American ED. The document analysis was used to explore the distinction between work-as-imagined (contained in the written procedures) and work-as-done (enacted by the staff) (Hollnagel, 2012). This was important for the study of RSs since, by definition, these skills are deployed to fill gaps in SOPs.

The feedback meetings consisted of presentations of preliminary results, made by one of the researchers to representatives of professionals. These meetings were useful both for giving feedback to professionals and for obtaining feedback from them, concerning the accuracy of the data analysis and interpretation made by researchers. Although obtaining new data was not the focus of the said meetings, this occurred opportunistically – e.g. in the USA, participants commented on the communication difficulties with patients who did not speak English. The researcher took notes from the meetings for subsequent analysis.

4.3. Data analysis

Five categories of data analysis were defined upfront (Table 2). RSs account for only one of these categories, and three others refer to contextual elements identified from: Hendrick and Kleiner (2001) on the sub-systems forming a socio-technical system (category 1), and Wachs et al. (2012) on the identification of NTSs from a RE perspective (categories 3 and 4). Hidden curriculum (category 5, Chuang et al., 2010) is closely related to the research question, and it was explicitly and spontaneously mentioned by an interviewee in the USA, who had an important role in the emergency medicine program. Overall, such data analysis categories provided a context for RSs, thus operationalizing the notion of the JCS as the unit of analysis.

The same procedures were adopted for analyzing data from all sources of evidence. Thus, when analyzing transcripts of interviews, diaries of observations, notes from meetings, and documents such as SOPs, researchers looked for excerpts of raw textual data that could support the identification of information related to the five data analysis categories mentioned in Table 2. An excerpt could consist of several lines of text, and be associated with all five categories. The identification of information related to data analysis categories (1), (3), (4), and (5) from excerpts was fairly straightforward. Concerning RSs (2), the search for evidence from the raw data was guided by identifying events in which professionals had to fill gaps in SOPs in order to achieve their goals, by relying on tacit knowledge and making sense of the interactions with other components of their broad socio-technical system.

The decision to highlight excerpts, rather than isolated words or expressions, contributed to overall understanding and the successful retrieval from the database of the context in which the outcomes were obtained. The vast majority of excerpts (about 90%) originated from CDM interviews and questerviews, which is in line with previous studies that point out the richness of information provided by those techniques (Crandall et al., 2006).

Excerpts, from the different sources, were recorded in two spreadsheets: one for each ED. Next, in a less abstract level of data codification, excerpts gave rise to examples (or instantiations) of RSs, work constraints, organizational support for RSs, and hidden curriculum that originated them – see the column on the right of

Table 1
Sources of evidence for investigating RSs.

Sources of evidence	USA	Brazil
Direct observations	Activities of the professionals: 45 h Training sessions: 20 h	Activities of the professionals: 110 h Training sessions: 10 h
Interviews using the critical decisions method	15 interviews, totaling 17 h: 3 technicians, 4 nurses, 8 physicians (attending physicians and emergency medicine residents)	19 interviews, totaling 19 h: 5 technicians, 5 nurses, 4 physicians, 1 manager, 4 patients
Interviews using the questerview method	5 interviews, totaling 4 h: 2 technicians, 1 nurse, 2 physicians	1 interview (1 h) with a hospital's director
Analysis of documents	None	Standardized operating procedures (SOP) used in the ED
Feedback meetings to discuss preliminary results with ED representatives	Four meetings totaling 2 h. Attended by 5 different reps of nurse technicians, nurses, residents, and physicians	Four meetings totaling 4.5 h. Attended by 5 different reps of nurse technicians, nurses and physicians

Table 2
Data analysis framework.

Categories of data analysis	Questions and/or information that was searched in the sources of data	Relevance to the research
(1) Characteristics of the socio-technical system	Characteristics of the four sub-systems that form a socio-technical system: social, work organization, technical, external environment	Identification of origins of RSs, contextual factors that could influence them, and leverage points to support their development
(2) RSs	Which are the skills deployed during resilient performance?	Identification and classification of RSs, which could be traced back to origins and contextual
(3) Work constraints	What does trigger resilient performance?	Same reason as category (1)
(4) Organizational support for the deployment of RSs	Which organizational measures support (or could support) the deployment of RSs?	Same reason as category (1)
(5) Hidden curriculum	How are RSs acquired?	Same reason as category (1)

Tables 4, 5 and 7. In a more abstract level of codification, examples were grouped according to their similarities – these groups correspond to the columns on the left of the Tables. Triangulation of data was made by comparing excerpts from different interviewees and different data sources.

Several rounds of reading raw textual data, identifying relevant excerpts, spotting examples from them, and grouping examples according to similarities were made to reach the lists presented in this paper. Thus, analysis had elements of both description (i.e. describing factual information on the system characteristics) and interpretation (i.e. codifying raw data into examples and categories). It is also worth noting that, although data were collected from different professional categories, data analysis was aggregated for the staff as a whole. This was made since interdependence is an essential feature of JCS, whether or not agents intend to act collaboratively.

5. Results

5.1. Overview of the investigated EDs

The EDs were described according to four subsystems that form a socio-technical system (Hendrick and Kleiner, 2001): work organization, social, technical, and external environment (Table 3). While both environments face similar problems (noticeably, overcrowding), some differences may be emphasized: (i) the American ED receives more patients in acute conditions, arising from severe traumas; (ii) there is a residency in emergency medicine in the USA; (iii) the Brazilian ED has a higher ratio technicians/nurses (3/1) in relation to the USA (0.5/1), and the nurses in the USA are more engaged in direct patient care; (iv) the use of IT systems and equipment is more disseminated in the USA; and (v) the Brazilian ED places less restrictions to receive patients, since it is fully dedicated to the national public healthcare system.

5.2. Resilience skills

Table 4 presents the identified RSs, along with some examples. As evidence of the construct validity of these RSs, they encompass the four core abilities of resilient systems proposed by Hollnagel (2011): (i) monitoring, since systems must know what to look for; (ii) anticipation, which refers to the ability of knowing what to expect and to anticipate threats; (iii) responding, as systems must know to respond to disruptions and disturbances by adjusting normal functioning; and (iv) learning, which indicates that systems must know how to learn the right lessons from the right experience. Associations between abilities and RSs are straightforward in some cases – e.g. "*monitoring* and recognizing the impact of small actions and decisions"; "anticipation of the need for actions and *anticipation*"; and "*responding* and re-plan the sequence of activities". Other RSs seem to hold relationships with multiple abilities depending on how they are deployed – e.g. communication may contribute to all four abilities. No RS seems to be fully dedicated to learning, which may indicate both a weakness of both EDs as well as that learning emerges from the joint use of several RSs.

Collaborative work was the RS category most frequently cited in both countries. According to Schöttle et al. (2014) collaborative work is characterized by a team solving problems and sharing responsibilities for achieving a common goal. A report by a technician (USA) illustrates that professionals are well aware of the relevance of this RS: *"sometimes nurses can't do what they need to do, if we (techs) don't do what we have to do first. And that goes back to the doctors, they can't get their diagnoses and do the things they need to do until the nurse and the tech have done their job"*. The importance professionals assign to this RS is in line with our assumption that the JCS should be the unit of analysis when investigating RSs.

Matching capacity and demand was the second most frequently cited RS. The need for this skill largely arises from overcrowding and variability of demand, which triggers the need for making decisions such as getting help from family members, and having patients sitting on chairs or aisles. These adjustments of the ED capacity sometimes create undesired interactions between patients, which can give rise to unexpected effects. Perrow (1984) mentions physical proximity between processes as a catalyzer for complex interactions.

Results also indicated that RSs are recursive – i.e. resilience demands more resilience. Therefore, there may be a hierarchy of RSs in a certain context, where the initial skill is of first order the next is of second order, and so on. For instance, the RS "matching capacity and demand (1st order)" may trigger the need for the RS "recognizing the impact of small actions and decisions (2nd order)". Indeed, as the decision is made to care patients on aisles, professionals need to be aware of the impacts of this situation. The mapping of networks of RSs may be important for the design of training programs (i.e. which are the RSs likely to be used together?) and for spotting work constraints that may act on the interface between RSs – in the above example, constraints such as heavy workload and lack of information on the patient health may lead to a decision of locating two incompatible patients side by side in an overcrowded area.

5.3. Work constraints

Results indicated a number of work constraints, which partially overlapped with those pointed out by earlier studies in EDs (Croskerry, 2014; Flowerdew et al., 2012; Pollarck et al., 2012). Table 5 presents the work constraints identified in this study as well as the number of excerpts from interviews associated with them.

Overcrowding was the most frequently mentioned constraint in

Table 3
Main characteristics of the EDs.

Description		USA	Brazil
Work organization	Medical specialties	Urgency and emergency: general practice, general surgery, and pediatrics Trauma	Gynecology
	Appointments	24/7. Admission through walk-in or ambulance About 86,000 annual appointments	About 54,000 annual appointments
	Capacity	Official capacity of 72 adult and 11 pediatric beds Overcrowding is commonplace	Official capacity of 41 adult and 9 pediatric beds
	Emergency residency	Yes, residents stay in the ED over three years.	No
		Residents of other specialties and/or undergraduate students stay in the EDs for about one month.	
	ED areas	Admission, ambulance intake, triage and treatment areas	
	Length of stay of patients	4 h on average	2 days on average
	Allocation of staff to ED areas	Professionals are allocated to ED areas and they stay in there most of their shift.	Professionals are assigned to patients, and therefore they (physicians) move between the ED areas as their patients move.
	Role of nurses	Nurses have a greater role in direct patient care.	Nurses work mostly as supervisors of technicians, who are the ones who work on the bedside.
Social	Main ED staff	50 physicians, 45 residents, 120 nurses, 60 technicians.	80 physicians, 20 last year undergraduate students, 8 residents, 40 nurses, 120 technicians.
	Other staff	Secretaries, guards, ED managers, ancillary studies staff, consulting physicians, respiratory therapist/physical therapist, pharmacist, paramedics (who bring some of the patients), undergraduate students (medicine or nurse college).	
		Chaplain, dialysis nurse	Social workers, psychologist
Technical	General	Work in the ED is supported by equipment related to patient care (e.g. mechanic ventilators, monitors) and to administrative tasks (e.g. computers).	
	Computerized system	A computerized system supports the management of information related to patients, such as charts and history of visits to the ED. Access to such information is limited according to the professional category – e.g. technicians do not have full access to charts.	
		All information related to charts and care of patients is available only in the IT system.	Regardless of the IT system, some information is only recorded in written format – e.g. vital signs and records of medication administration.
	Communication between employees	A pager is used to facilitate communication between the care team, especially of critical patients.	A social network software is used to communication between the ED management.
	Medication Access	There is no pharmacy within the ED. All medications are available from the automatic dispenser of drugs.	Medication is stored in the ED pharmacy. Medications received from the pharmacy are then stored in drawers and shelves within each unit.
External environment	Inside hospital	Sometimes professionals from other specialties are requested to go to the ED to help on the diagnosis and/or treatment plan. The other hospital units receive the admitted patients, after they get stabilized on the ED. A drawback refers to the fact that patients can only be transferred to the other areas of the hospital when there are inpatient beds available. Also, both ancillary studies and other units can influence the ED workflow.	
	Outside hospital	Professional game season, medical transportation system. ED receives patients covered by health insurance. Of course, patients who do not present insurance in reception are received anyway, and the bill is sent afterwards.	The ED only receives patients through the national public healthcare system – people from several cities, sometimes far away from the ED, search for being cared there as the hospital is a reference in many medical specialties.
		Weather conditions, time of the day, day of the week, another hospital condition	

Table 4
Resilience skills.

RS categories	N. of excerpts total (USA/BRA)	Some examples
Collaborative work	94 (45/49)	Get help from/help other area's staff, know to role of each one in the team
Matching capacity and demand	60 (36/24)	Create extra beds by placing two patients in the space usually occupied by one patient, have patients sitting on chair, on aisles or hallway
Communication	53 (29/24)	Give the correct information on the right time, look for and rely on complementary or available sources of information, such as family member, old records
Recognize the impact of small actions and decisions	49 (27/22)	Recognize the impact of having patients on aisles, hallway or chairs, such as patient discomfort and worsening of their conditions
Prioritize actions and decisions	39 (17/22)	Analyze the patient chart and prioritize more critical or difficult patient
Identify contextual factors that can hinder performance	35 (21/14)	Awareness of the other department's or other professional high demand of work, awareness of impact on the long waiting time
Anticipation of the need for actions	29 (20/9)	Anticipate the arrival of a critical patient, anticipate the need for lab work
Managing the trade-off between time allocated to care patients and number of patients seen	27 (14/13)	Manage the time with each patient
Re-plan the sequence of activities	26 (15/11)	Re-plan the sequence of activities, according to the appraisal of actual status of operations
Leadership	22 (13/9)	Delegation of tasks
Workarounds involving the use of equipment and materials	17 (14/3)	“Over stock” material, get equipment from another area
Total	451 (251/200)	

Table 5
Work constraints.

Categories of work constraints	N. of excerpts total (USA/BRA)	Some examples
Overcrowding	156 (59/97)	High number of patients, patient misperception of emergency services
Resources	63 (26/37)	Lack of equipment, material, staff
Information	51 (21/30)	Incomplete/inaccurate information, lack of communication between areas
Patient flow	45 (21/24)	Lack of beds for admitted patients, hold patients while waiting for admission
Workload	45 (7/38)	Stress, frustration, annoyance
Profile of patient	37 (26/11)	Psychiatric or violent patient, high level of acuity
Administrative work	23 (12/11)	Charting is time consuming, administrative paperwork
Ancillary Studies	20 (18/2)	Results of exams are delayed, patient is not ready for the exam
Time	18 (7/11)	Time pressure, balancing time between teaching and caring patients
Critical events	10 (5/5)	Mass casualty incidents
Total	468 (202/266)	

both countries. Indeed, this is a well-known ED problem worldwide (Epstein et al., 2012), posing safety hazards and stretching the use of resilience to its limit. Factors internal (e.g. inefficient work flows) and external to the EDs (e.g. overcrowding in the EDs of other hospitals) were reported in the interviews as playing a role in overcrowding.

Only 5 out of the 19 examples associated with overcrowding were the same in both countries. One of these was "patient misperception of emergency services", which refers to patients that could be cared in primary healthcare facilities instead of an ED. A report by a technician (USA) illustrates the frustration of professionals with this problem: "*… patients need to go to their doctor's office, to primary care, versus coming to the hospital. It is getting to the point that it is not really a hospital anymore, it is a primary care doctor's office*". In the Brazilian ED, a stricter admission process has been enforced recently, and patients with less serious conditions have been diverted to primary care facilities. However, according to reports by several members of staff, it turned out that overcrowding remained the same as previously and even aggravated by the fact more patients with serious conditions now have to be cared without any additional resources. The removal of the buffer provided by patients in better conditions can contribute to problems, such as high stress levels of employees.

There were several pieces of evidence that work constraints trigger the use of RSs (see example in Section 5.2, regarding overcrowding – a work constraint – and matching capacity and demand, a RS). Table 6 presents the relationships between work constraints and RSs as realized by the researchers, based on the empirical data. This Table indicates that individual RSs are triggered by the interactions from four (in the case of RS 7) to ten work constraints (in the case of RS 6). It is possible that the variety and intensity of work constraints is a proxy measure of the complexity of the work situation, and therefore of the need for using RSs – this might be investigated by future research.

Table 6
Relationships between work constraints and RSs.

Work constraints\RS	1	2	3	4	5	6	7	8	9	10	11	Total
Administrative work	X		X	X	X	X		X		X	X	8
Critical events	X	X	X	X	X	X	X	X	X	X	X	11
Workload		X	X	X	X	X	X					6
Information	X	X	X		X	X	X	X		X		8
Resources		X		X		X			X		X	5
Profile of patient	X	X	X	X	X	X		X	X			8
Time		X	X	X	X	X		X	X	X		8
Overcrowding	X	X	X	X	X	X	X	X	X	X	X	11
Exams	X	X	X	X	X	X			X		X	8
Patient flow		X	X	X	X	X		X	X	X		8
Total	6	9	9	9	9	10	4	7	7	6	5	

Notes: 1 – anticipation of the need for actions; 2 – collaborative work; 3 – communication; 4 –matching capacity and demand; 5 –managing the trade-off between time allocated to care patients and number of patients seen; 6 –Identify contextual factors that can hinder performance; 7- leadership; 8 – prioritize actions and decisions; 9 – recognize the impact of small actions and decisions; 10 – re-plan the sequence of activities; 11 – workarounds involving the use of equipment and material.

5.4. Organizational support for the development of RSs

Table 7 presents the types of organizational support for the use of RSs. This is a key data analysis category, since it makes it clear the responsibility for being resilient does not rest solely on the front-line shoulders. It is noteworthy that just 7 out of the 39 examples were the same in both EDs (17.9%), which is in contrast with the results related to work constraints (35.4%) and RSs (43%). A possible interpretation for these findings is that, although the nature of work and front-line employees' performance is similar across the EDs, the nature and amount of resources available to support resilience varies more substantially – this interpretation is also backed by the aforementioned characterization of the EDs (see Section 5.1). The differences in organizational support also indicate mutual learning opportunities between the EDs.

An example of organizational support detected mostly in the USA was "support for collaborative work". One of the areas of the American ED is responsible for a high number of patients who require close monitoring. The ED management divided the team working in that area in two sub-teams, but simultaneously encouraged workers from one sub-team to help the other sub-team whenever required. In this case, the organizational support focused on the RSs "collaborative work" and "matching capacity and demand". An example of support detected only in Brazil was the use of a multidisciplinary team to define the plan of care for patients. One of the support measures present in both contexts was "rotation of workers between ED areas", so they know the flow of each area. Overall, the three aforementioned examples of organizational support encourage the development of RSs since professionals increase their repertoire of work strategies, and may anticipate the impacts of their actions and decisions on other areas of the ED, and on the work of their colleagues.

5.5. Hidden curriculum and the learning of resilience skills

While all measures described in the previous section support the use of RSs, some of them also offer means for learning these skills (i.e. those marked with *). These support measures enhance the hidden curriculum, which is the unplanned learning that occurs during everyday practice through trial and error, and which may

Table 7
Organizational support for RSs – measures marked with * also play a role as hidden curriculum for learning RSs (see Section 5.5).

Categories of organizational support	N. of excerpts total (USA/BRA)	Some examples
Contingency plans for crisis management	46 (6/40)	Support to deal with violent patients Development of plan for handling mass casualties Organization support during crises Extra automated medication dispensing system for mass casualty incidents Using mass casualty incident protocols whenever five or more critical patients arrive at the same time, even if patients are not from the same event
Support for collaborative work	24 (13/11)	* Multidisciplinary rounds Allocate more employees on the busiest hours Possibility of calling in more staff in times of need * Multi professional team of care (Multi professional residency) * Staff with high levels of expertise in most critical areas * Help from supervisors or managers Re-distribute staff according to demand * Preceptors for new employees Define teams for the busiest areas * Help from charge nurse
Standardization of managerial and care processes	20 (4/16)	Development of protocols aimed at standardizing care Re-design of the process to transfer the patient to the unit, once there is an open bed Ensure that other areas of the hospital take responsibility over admitted patients that are still on the ED waiting for beds Accredited quality management system *Investigation of adverse events * Meetings on a regular basis involving the ED management to discuss ED routines Full-time pharmacist in the ED Protocols to prioritize patients in triage
Computerized system	13 (2/11)	Ease of access to SOP Use of electronic medical record (EMR) for updating location of patients
Management of human and material resources	11 (7/4)	List of equipment plugged on the “generator plug” Good policy of promotions and career progress Full-time employee for managing stocks of materials and equipment Back up equipment * Rotate staff between ED areas Training on the use of new equipment Full-time time dedicated to transport patients between the ED and other areas of the hospital
Strategies for dealing with patients that should be cared in primary care facilities	9 (4/5)	Diverting patients in less serious conditions to primary care facilities Care plan for chronic patients, as an attempt to prevent unnecessary readmissions Development of formal document of narcotics and narcotics database
Measures to deal with lack of beds for admitted patients	8 (7/1)	Possibility of using beds in other areas of the hospital Holding areas Open beds in another unit Re-assess and discharge patients in other departments
Total	131 (3/88)	

occur as an unexpected by-product of formal organizational routines (Flowerdew et al., 2012; Murakami et al., 2009). Indeed, skills developed from hidden curriculum are not *explicit* in classes, seminars and books (Chuang et al., 2010).

Overall, 76 excerpts of interviews made reference to hidden curriculum. Three reports are illustrative: (i) “*when deciding who is going to medicated first … there is no school for teaching this … it comes from experience, you learn what needs to be prioritized*” (technician, Brazil); (ii)“*it is really about deciding who needs immediately attention and who can wait and that is something that comes with experience*” (resident, USA); and (iii)“*you look at people that have years of experience doing that, the ones that have been there for a while and you learn from them, you watch what they do and learn from your environment*” (technician, USA).

Interviews and observations revealed three interrelated mechanisms through which hidden curriculum develops: (i) experience arising from trial and error; (ii) novices working under the supervision of experts or simply observing experts in action; and (iii) training programs and teamwork routines which offer opportunities for employees being exposed to a wide variety of problem-solving situations, perspectives and feedback from co-workers – e.g. rounds or pre-shift meetings, residents' weekly meetings, simulation center, and disaster drills. Mechanism (iii) has already been mentioned in RE literature. For instance, Siegel and Schraagen (2015) presented a case study of developing RSs of rail signal operators based on team reflection at the end of their shift – this reflection was described as a means for making implicit knowledge explicit. Saurin et al. (2014) developed a scenario-based-training program for developing RSs of grid electricians.

The downside of hidden curriculum, which was detected in the case studies, is that it may perpetuate ineffective workarounds that are (wrongly) taken for granted (Chuang et al., 2010). For instance, the RS “workarounds involving the use of equipment and materials” seemed to be overused in the Brazilian ED – e.g. researchers observed, several times, that vital signs of patients were not measured in the right time as a result of lack of equipment. Sometimes staff brought their own personal equipment in order to deal with this drawback.

6. Discussion

6.1. Resilience skills as emergent phenomena

Literature review and data from case studies allowed the development of a model that connects the constructs used in the data analysis. This model describes both the acquisition of RSs and their deployment and use as emergent from the interactions between (Fig. 1): (i) work constraints; (ii) hidden curriculum; (iii)

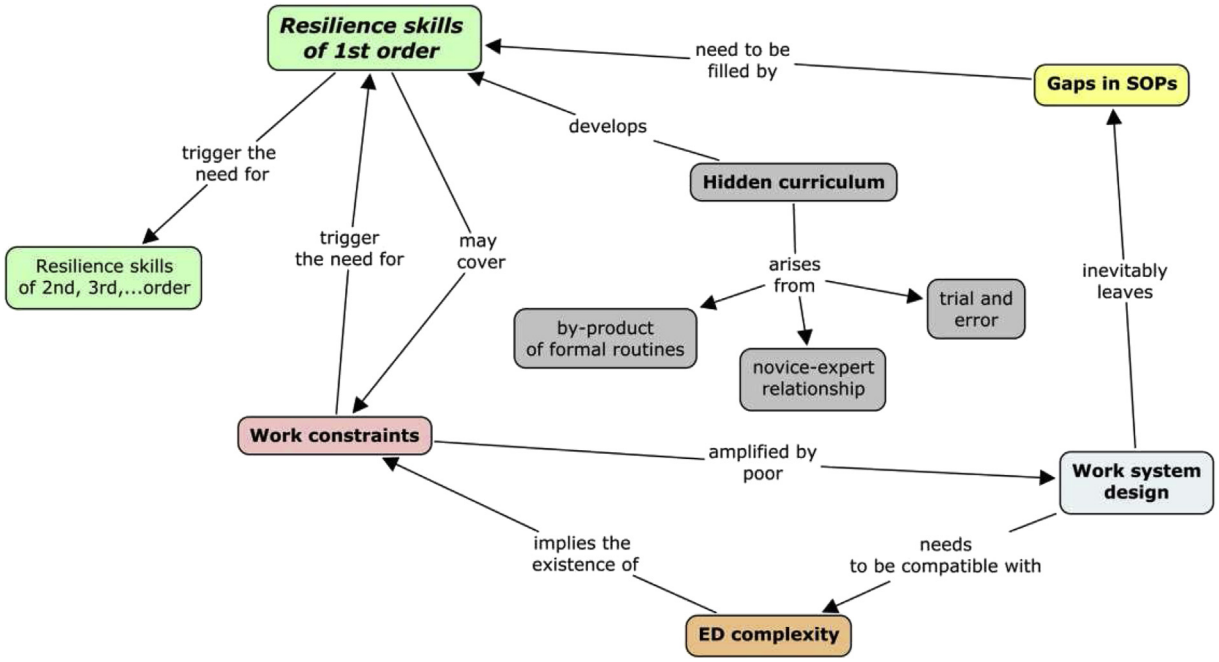

Fig. 1. Resilience skills as emergent phenomena. Notes: (i) key concepts in bold; (ii) colors represent groups of similar concepts that contribute to the emergence of RSs.

work system design; (iv) the recursive nature of RSs; (v) characteristics of complexity in the socio-technical system; and (vi) gaps in SOPs.

Also, the model indicates that: RSs are sometimes used more frequently and with greater intensity than necessary (i.e. they are overused) due to poor work system design; and there is a bi-directional relationship between RSs and the work constraints. By maintaining the system producing its outputs even under critical conditions, it turns out that RSs may contribute to covering poor work system design. Therefore, the use of RSs may produce a feedback loop where resilience demands ever more resilience. This cycle may only stop, temporarily, when the system runs out of adaptive capacity and stops producing outputs (e.g. due to an adverse event). It is also worth noting that there might be other contributing factors for the emergence of RSs, which were not identified in this study. A greater number and diversity of contributing factors for RSs would be beneficial, since this would provide redundancy of sources of resilience and develop a richer repertoire of complementary skills.

6.2. An instantiation of the model

In this section, an instantiation of the model is presented, based on a CDM interview carried out in the American ED. Over the description of the event, work constraints (WC), organizational support (OS), and RSs are highlighted. Table 8 summarizes how these and other elements of the model played a role in the described event. Also, Table 8 indicates that it is possible to trace observable field phenomena back to the abstract constructs used in the model. Therefore, the conclusions made from applying the model are verifiable.

The event occurred in the trauma area and it was reported by a

Table 8
Instantiation of the elements of the model.

Elements of the model	How the elements appeared in the instantiation
Resilience skills of 1st order	**RS1** Collaborative work; **RS2** Manage the trade-off between time allocated to care patients and number of patients seen; **RS4** Identify contextual factors that can hinder performance; **RS7** make clear what the care plan is for other professional, patient, or family; **RS5** Anticipate the need of actions (setup resources to receive an incoming patient); **RS8** prioritize more critical or difficult patient
Resilience skills of 2nd order	**RS3** Recognize the impact of small actions and decisions
Resilience skills of 3rd order	**RS6** communication (communicate about the patient condition with other professional or family)
Work constraints	**WC1** patient (non-compliant, high level of acuity); **WC2** resources (staff); **WC3** overcrowding (high number of critical patients); **WC4** information (multiple people asking to do things or provide information); **WC5** time pressure; **WC6** resources (lack of immediate help from colleagues); **WC7** workload; **WC8** administrative work (chart is time-consuming)
Gaps in SOPs	SOP does not take into account the fact some patients may be unattended when a nurse has to transport a patient to an exam area
Organizational support/work system design supporting RSs	**OS1** support for collaborative work
Hidden curriculum: novice-expert	As part of her report, the nurse mentioned that *"the cool thing, my coworkers, a lot of them are really seasoned, like a lot of them have been nursing longer than I've been alive"*
Hidden curriculum: experience by trial and error	On the spot decisions made by the nurse over this event involved trial and error, even though learning may have been compromised by the lack of feedback from colleagues and reflection afterwards
Hidden curriculum: by-product of formal routines	Not identified in this event
ED complexity	The reported event illustrates several attributes of complexity, such as unexpected variability (e.g. the exact time of arrival and profile of incoming patients), diversity (of patients, of staff roles, skills, and medication), and dynamic interactions between agents

nurse who had been working there for six years. In the early hours of the shift (about 8 am) the nurse was assigned to care a recently admitted patient, who had been seriously injured in a motorcycle accident. One of the first difficulties for caring the patient was his refusal to be laid down (**WC 1**) – he just agreed to do this after the nurse asked for help (**RS1, 1**st **order**) from the physician, who was able to convince the patient (**OS 1**). Next, the patient needed magnetic resonance imaging, and according to the SOP the nurse should go along with him to the exam area. However, by following the SOP the nurse would leave another colleague as the sole responsible for the whole trauma area over more than one hour (**WC 2**).

Given the need for managing this trade-off (giving full attention to one patient *versus* leaving many others under the care of an overloaded colleague, **RS 2, 1**st **order, which triggered RS 3, 2**nd **order**), the interviewed nurse made the decision to deviate from the SOP and stay in the trauma area. She requested that staff from the resonance area monitored the patient's condition (**RS 6, 3**rd **order, triggered by RS 3, 2**nd **order**), caring him during the whole process. It turned out that the exam went well and the patient returned to bed 2, in the trauma area.

About 2:30 pm the trauma area was overcrowded (**WC 3**). In the words of the nurse, it "*just exploded people on hallways*, *we only had five beds and everybody in them were very sick*". The nurse reported to the medical team that the patient in bed 2 was suffering from pain and then the physician prescribed additional pain relief medication. Meanwhile, family members were unease about the pain of bed 2's patient, pressing nurses to act quickly (**WC 4 and WC 5**). According to the nurse, family members "*did not understand*, *it was their loved one … they did not understand where we were coming from or what we were doing. So*, *I just tried to appease the family as best as I could*" (**RS 7, 1**st **order**).

The situation became more complicated as at about the same time another patient in serious conditions had just been admitted and allocated to the interviewed nurse (**WC 3, getting worse**). This patient needed an urgent tomography and the nurse transported him to the exam's area. Fortunately, about this time (3 pm) a third nurse had just started her shift (**OS 1**), thus replacing the interviewed nurse while she was away. As the patient that had been in tomography returned, he was restless (**WC 1**) and had to be sedated; he was placed on bed 4.

However, the patient in bed 2 also needed sedation, and there was no staff immediately available (**WC 6**) for setting up this task. As to the interviewed nurse, she was "*back and forth*" between beds 2 and 4 (**RS 2, 1**st **order**). In a certain moment, the nurse needed to move bed 2's patient around. After receiving negatives from some colleagues (**WC 6**) she eventually got help from the nurse in charge of the ED (**OS 1**). Another interruption arose when a physician requested help from the interviewed nurse (**WC 4 and RS 1, 1**st **order**), in order to give medication to bed 4's patient, who appeared to be in convulsion.

Additional stress was caused by the information that a new patient (**WC 3, RS 5, 1**st **order**), in a very serious condition, was due to arrive in a few minutes, while the patient on bed 2 (now set up for sedation) had a serious worsening on clinical conditions. This triggered immediate support from the medical team of another ED area (**OS 1**), who took charge of bed 2's patient and realized the intubation procedure. The interviewed nurse then prioritized this patient (**RS 8, 1**st **order**) until the arrival of a neurosurgical team, who assessed the patient and made the decision that an urgent surgery was needed. In the meanwhile, bed 4's patient had already been sedated, had mechanical ventilation, and was stable. The described situation illustrates successful outcomes arising from resilience, although at the expenses of working overtime (**WC 7**) and of delaying administrative work (e.g. charting patients) (**WC 8**), which may also have clinical implications (**RS 5**).

The instantiation aforementioned also makes it clear that the use of RS occurs on an everyday basis by "normal people", in the sense that they do not necessarily involve extraordinary actions by outstanding performers – of course, these are possibly more effective when using RSs. Thus, opportunities for observing, learning, and improving RSs are ubiquitous. The discussed event also suggests that the four abilities of resilient systems may be deployed in any sequence – i.e. a linear sequence of monitoring, anticipating, responding, and learning, should not be expected. Indeed, the first RS used in the given example (ask help) was a response to a disturbance. This insight has implications for the design of RS training programs. Lastly, the event suggests that it is possible to spot ED operations likely to have gaps that require RSs. For instance, the discussed event involved the activities of intubation, patient transportation, administration of drugs, and admission of new patients.

7. Conclusions

7.1. Contributions of this study

The question that guided this research had been stated as "where do RSs come from?" Case studies of EDs in two countries indicated that acquisition and use of RSs was largely a by-product of the interactions between factors that cannot be fully controlled by management, such as work constraints, hidden curriculum, and the inevitable gaps in work system design. As such, this work provides empirical evidence and a theoretical framework for describing RSs as emergent phenomena. Indeed, the key property of RSs (i.e. resilience) is not found in any of the interacting elements, thus being a novel property arising from interactions. In particular, this research is distinct from previous studies to the extent it has gone beyond detailed descriptions of resilience or its absence. It went beneath the surface to offer an explanation regarding where resilient performance comes from, and what factors support or degrade it. Another key aspect of the approach we followed, in comparison with other paradigms that stress the isolated individual worker or team as the unit of analysis, is the recognition of the role played by the work environment and by management. Thus, an important question raised by our approach is "how can we design a *system* that supports people and positively influences the acquisition and use of RSs", instead of "how can we train people to use RSs according to SOPs".

While results indicate that the development of RSs is largely a spontaneous process this does not exclude the idea of intentionally influencing it. For instance, hidden curriculum could be made more explicit, such as by the creation of opportunities for reflection from practice (guided by a theoretical framework oriented by resilience engineering) and scenario-based training focused on RSs. Furthermore, data made it clear management can influence RSs in two other complementary ways: by tackling work constraints; and by providing organizational support for dealing with the remaining inevitable constraints.

With regard to practical contribution, the data collection and analysis method adopted in this study is a means of generating descriptive knowledge that can be translated into prescriptions for managing operations in EDs. For instance, identification of RSs and work constraints sets an important basis for the re-design of training programs, since it indicates which skills should be trained and which factors should be included in training simulations. Similarly, the re-design of SOPs may benefit from the adopted method – e.g. realistic SOPs should account for work constraints. Lastly, the lists of constraints, RSs, and organizational support measures can be useful for other EDs, given that this study

indicated the nature of front-line work seems to be similar across countries. It is worth noting that the mentioned lists need to be constantly updated and extended.

7.2. Limitations

Three main limitations should be emphasized. First, while the qualitative approach is strength of this research, it needs to be complemented by quantitative studies. For instance, correlations between the elements of the model presented in Fig. 1 could be assessed, as well as between those elements and ED and hospital performance metrics and resilience at the organizational level.

Second, while this study conveyed the message that a portion of resilience is unnecessary, it did not provide tools for identifying the normal or tolerable threshold of it. Third, while personality traits and other individual characteristics may have a role in the origin of RSs, this was not assessed in this study.

7.3. Future studies

Some opportunities for future studies arise from this research, as follows: (i) to carry out a similar investigation of RSs focusing on higher hierarchical ranks; (b) to conduct quantitative studies to find the extent to which the use of RSs is correlated to ED and hospital performance as well as to organizational resilience; and (iii) to translate descriptive knowledge of RSs into prescriptive knowledge. As to this last suggestion, a design science research approach would be appropriate for developing and testing methods and tools for influencing the development of RSs in a positive manner. For example, as a sequel of this study, a method will be developed for the integrated design of SOPs and training, mapping gaps in the former that should be dealt with by the latter.

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