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The effects of Multitasking on Stress and Situational Awareness: A multi-source study in the Emergency Department

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List of abbreviations

MT (Multitasking)

SA (Situational Awareness)

ED (Emergency Department)

M (Mean)

SD (Standard Deviation)

STAI (State Trait Anxiety Inventory)

CA (Crohnbach's Alpha)

Summary

Emergency Department (ED) providers work in a complex environment, where unknown patients with unknown, sometimes severe diseases need to be taken care of with sometimes minimal time resources. This makes it unavoidable to frequently execute tasks concurrently. The aim of this study was to investigate the prevalence of Multitasking (MT) in an ED as well as the impact of MT on ED providers' stress and their Situational Awareness (SA). And finally, we aimed at identifying both possible dangers for patients' safety and also potential for better patient care.

A mixed-methods approach was used by observing physicians and nurses in a German interdisciplinary ED during 80 sessions of 90 minutes, respectively. We systematically observed which tasks the providers were performing concurrently (i.e., MT proportion). These findings were compared to the results of a questionnaire completed by the observed provider after each session. We additionally assessed further workload parameters in the ED.

On average, ED providers performed MT for 6 minutes per hour (physicians: 8 minutes, nurses: 5 minutes). Most common tasks involved in MT were documentation and communication with patients or colleagues. Self-assessed stress levels were at 2 out of 4 points with low variance. Nurses reported significantly higher stress levels with increasing number of patients; physicians' stress levels were not associated with any of the workload parameters. Physicians reported higher SA when performing MT to a larger extend, and also when treating high-risk patients. Concerning the individual SA-questions, the impact was judged most prominent on predicting future developments resulting from their efforts.

This study shows that MT forms a significant part of ED providers' daily work. MT as well as professional challenges seem to stimulate ED providers' SA with the obvious goal to improve diagnostic and therapeutic decisions. We also found that not all tasks can be combined easily with each other. Based on our findings, we suggest that ED providers are aware of and trained systematically in MT to minimize potential risks of serious mistakes.

Zusammenfassung (deutsch)

Mitarbeiter in Notaufnahmen arbeiten in einem komplexen Arbeitsumfeld. Unbekannte Patienten mit teils kritischen Krankheitsbildern müssen in kurzer Zeit untersucht und zumindest anbehandelt werden. Hierbei werden häufig mehrere Tätigkeiten gleichzeitig ausgeführt. Ziel dieser Studie war, herauszufinden wie häufig Multitasking (MT) angewandt wird und ob MT Auswirkungen auf das Stressempfinden der Mitarbeiter sowie deren Situationsbewusstsein hat. Letztendlich sollten mögliche Risiken für die Patientensicherheit, aber auch Chancen für eine bessere Patientenversorgung aufgezeigt werden.

In der interdisziplinären Notaufnahme eines kommunalen Krankenhauses der Maximalversorgung wurden Ärzte und Pflegekräfte in 80 Arbeitseinheiten von je 90 Minuten beobachtet und systematisch alle Tätigkeiten notiert. Zusammen mit einem im Anschluss an jede Beobachtungseinheit durch die beobachtete Person ausgefüllten Fragebogen sowie unabhängig erhobenen Daten über die Auslastung der Notaufnahme wurden daraus Schlüsse zu Stressempfinden sowie Situationsempfinden der Mitarbeiter gezogen.

Die Mitarbeiter der Notaufnahme führten im Schnitt während mehr als 6 Minuten pro Stunde mehrere Tätigkeiten gleichzeitig aus (ärztliches Personal: 8 Minuten, pflegendes Personal: 5 Minuten). Häufigste MT waren dokumentierende Tätigkeiten und Gespräche mit Patienten oder Kollegen. Der Stress-Pegel war bei allen Gruppen konstant bei etwa 2 von 4 Punkten. Für das pflegende Personal ergaben sich mit steigendem Patientenaufkommen höhere Stress-Pegel, für das ärztliche Personal war kein Einfluss dieser untersuchten Faktoren feststellbar. Für das ärztliche Personal verbesserte sich das Situationsbewusstsein einerseits mit steigendem Zeitanteil von Multitasking und andererseits ebenfalls mit einer steigenden Anzahl an Hochrisikopatienten. Für die Einzelfragen zeigte sich eine Zunahme des Situationsbewusstseins in Bezug auf das Voraussehen der zu erwartenden Entwicklungen.

Diese Studie zeigt, dass Multitasking, ebenso wie der Anteil von Hochrisikopatienten mit einem gesteigerten Situationsbewusstsein des Personals einhergehen. Möglicherweise, um Entscheidungen zu Diagnose und Therapie zu verbessern. Unsere Beobachtungen deuten darauf hin, dass nicht alle Tätigkeiten beliebig kombiniert werden können. Im klinischen Alltag sollten die Risiken von Multitasking bewusst gemacht oder auch gezielt trainiert werden, um schwerwiegende Fehler zu vermeiden.

1. Introduction

1.1. Multitasking – risks and potential

It is obvious from typical situations in emergency departments (EDs) that medical staff frequently need to look after more than one patient at the same time and thereby may face complex and even stressful situations. In other words, staff in EDs regularly are compelled to perform multiple tasks at one time (Adams and Rho 2016).

1.1.1. Risks of Multitasking

Potential risks of MT repeatedly have been addressed for situations outside of clinical work. Non-medical research on driver distraction (Ishigami and Klein 2009, Carney, Harland et al. 2016) and instant messaging (Bowman, Levine et al. 2010) showed an increasing number of unexpected outcomes up to obvious errors when the demand for MT grew in frequency and complexity. Furthermore, it was shown that there was a significant likelihood of not finishing a first task, if a second task absorbed the attention of a test person (Skaugset, Farrell et al. 2016). Drawing a conclusion out of these findings, the difficulty with MT is to identify "situations where doing MT is inappropriate" (Adams and Rho 2016).

1.1.2. Benefits of Multitasking

On the other hand, a MT approach apparently may be judged helpful to organize a given set of tasks in such a way so that they logically fit together, as this can help to reduce the cognitive load required by persons who perform these tasks (Reiman, Weaver et al. 2015). Furthermore, both in professional and private life, every now and then, we feel like accelerating things by performing multiple tasks at the same time. Moreover, sometimes MT even is considered a necessary skill, e.g. definitely required in the context of residents' curriculum and work in hospital in general (Heng 2014, Skaugset, Farrell et al. 2016).

1.1.3. Definitions of Multitasking

Research in cognitive science reveals that as a matter of fact we cannot really allocate attention to multiple tasks at the very same time (Skaugset, Farrell et al. 2016). The term MT is being commonly used for situations which are about to manage more than one task within a short period of time. In order to be more precise, authors differentiate between different forms of MT: (1) *concurrent* MT, meaning that two tasks are being performed simultaneously

or in a way of switching very fast and repeatedly from one to the other and back, and (2) *interleaved/sequential* MT, where the subject pauses the first task for a longer period in order to slip into another one (Salvucci, Taatgen et al. 2009).

Furthermore, researchers differentiate whether MT includes different tasks using the *same* or *different modalities* (i.e., verbal/auditory/visual). Or, whether MT is *prompted* externally or *voluntarily* (Douglas, Raban et al. 2017). Recently, it has been criticized that previous studies in health care environment do not consider sufficiently these three criteria (Douglas, Raban et al. 2017).

Until now, only few studies are available that investigate prevalence of MT in EDs. Moreover, these studies use different definitions for MT such as the number of patients overseen simultaneously, or the number of tasks performed per hour. This results in different definitions of MT used in literature (Abdulwahid, Booth et al. 2018). In order to overcome these shortcomings, common classification standards and systematic methodologies are needed for the investigation of MT in ED.

In a nutshell, previous research on MT in acute care environments is scarce and it lacks conceptual clarity, so that further studies are necessary to strive for a better understanding of the negative and positive effects of multitasking within work systems in clinical care.

1.2. Stress

1.2.1. Definitions of Stress

Over time, psychological stress has been defined in different ways. Originally, stress was associated to a pressure that was prompted on the subject from outside. Later, stress was referred to as the overreaction of an individual. Following more recent conceptualizations, stress is defined as the combination of an externally prompted pressure on a subject with a lack of efficient mechanisms to cope with the situation (Basu, Qayyum et al. 2017). As a consequence, stress can be considered neither as purely objective nor as a subjective construct, since it always depends on the interplay of the specific situation and the subject's individual perceptions and strategies to master this situation.

1.2.2. Effects of Stress

Acute stress not only affects the individual's feeling but also impacts the behaviour (Michie 2002). Thus, stress may cause fatigue and lapse of concentration but it can also lead to aggressiveness which obviously might result in dangerous situations when this occurs in a challenging environment such as an ED. By an experimental simulation it was shown that increasing levels of stress lead to a more and more narrowed attentiveness and, additionally, to a loss of team performance (Driskell, Salas et al. 1999). Furthermore, and in addition to acute effects, chronic stress has been reported to provoke long-term changes in neuroendocrine, autonomic and immunological systems with increasing likelihood of physical and mental diseases (Michie 2002). Indeed, it has been alleged that each single stressful experience in case of frequent exposure may cause some kind of mental illness such as depression. And medical staff in particular is considered to be at risk, being afflicted with exceptionally high levels of mental distress and exhibiting higher suicidal rates than average population (Lindeman, Läärä et al. 1996, Burbeck, Coomber et al. 2002). But even without taking into account those potentially fatal effects, stress obviously creates economic problems: for stress is seen to provoke cardiovascular diseases and depressions which in turn are believed to count among the main reasons for health related reductions in earning capacity (Rothe, Adolph et al. 2017).

1.2.3. Stress in Emergency Medicine

So far, there has been only limited research on the effects of stress for medical staff in emergency departments. Different studies set out to identify key stressors in ED. The following stress factors were mentioned mostly: high workload, shortage of staff and the systematic lack of autonomous working options due to a non-supportive work environment (Flowerdew, Brown et al. 2012, Basu, Qayyum et al. 2017). Moreover, the breakdown of team communication was shown to aggravate stress levels for providers of medical services (Estryn-Behar, Doppia et al. 2011). Notably, there was only one study that claimed suffering patients being a major stressor (Adeb-Saeedi 2002). Therefore, it may be concluded that stressors in ED are not exclusive for the ED environment but are just the same stressors that could occur in any other clinical environment (or even outside of the hospital). Yet, rates of burnout are higher in ED physicians than in the general population (Xiao, Wang et al. 2014) and even higher than among physicians of other specialisations (Estryn-Behar, Doppia et al.

2011). Another study analysed the impact of interruptions during an ongoing workflow: it was found that interruptions were most stressful when they resulted from sources of information referring to different patients who had been entrusted to the responsibility of ED staff in parallel to each other (Weigl, Beck et al. 2017). Considering the limited knowledge on stress factors in ED, this research project aims at surveying whether MT influences the ED providers' stress level.

1.2.4. Hypothesis

Given these previous findings, we suspected factors like high work load, high job demand, poor teamwork and increased stress levels as risks to patient safety (Rasmussen, Pedersen et al. 2014) on the one hand, but also as a danger to the healthiness of staff in ED on the other hand. This prompted us to further investigate the influence of MT on the stress level of ED providers.

1.3. Situational Awareness

1.3.1. Definition

Situational Awareness (SA) is a concept that has been around for quite some time but was crucially influenced by Mica Endsley's seminal publications: She defines SA as "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of the status in the near future" (Endsley 1988, p. 792). Or, as she puts it in simpler words: "knowing what is going on" (Endsley 1995b, p. 36). Initially developed for aviation research, her concept has largely been adapted to other sectors and is now widely used to improve the work environment of physicians. Endsley proposed three distinct levels or components of SA: (1) P*erception* means to receive information of every kind of environmental elements. (2) *Comprehension* means to understand the meaning of the received information and to interpret what is happening in the current situation, and (3) *projection* onto the future means to predict what is going to happen in the upcoming moments (Endsley 1995b). In other words: Out of given inputs, the subject derives its own *mental picture*, makes decisions, executes tasks and gives instructions. In order to make the appropriate decision for a particular situation, it takes a good SA: meaning that the subject's *mental picture* overlaps in an optimal way with the actual situation. Thus, the challenge is not only to get most of the information "provided" by

the situation, but also to correctly interpret and understand this information. Keeping this in mind, it is obvious that any short coming of the individual's SA can lead to a false decision and, if the worst comes to the worst, this can put lives at risk. This problem has been addressed in the context of aviation far earlier than in medical environments. Jentsch, Barnett et al. (1999), for instance, analysed 300 aircraft incidents and showed the effect of insufficient SA to cause incidents or even accidents. For a medical environment, however, we are still missing a comprehensive analysis of SA related incidents.

1.3.2. Measurement

Basically, the quality of SA is being assessed by comparing the subject's *mental picture* of the situation with the actual situation. Quite obviously, however, we face severe problems to measure instantaneously all necessary parameters that are needed in order to describe all relevant perceptions of the subject and to compare this picture to the actual situation. Therefore, different techniques have been developed and introduced to approach an appropriate SA measurement:

Generally, a simulation setup can help to simplify a specific task or process so that simple *objective* parameters can be used for characterization. In real life as we experience it in an emergency situation, however, *objective* parameters will be far too complex to be measured in a practical way. As a result, researchers might resort to a *subjective* assessment in order to measure the SA in such situations.

In the case of objective parameters, Gugerty (2011) differentiates between *online* and *offline* measurements of SA. Online measurements allow to assess SA directly without interrupting the simulation setup, by using online monitoring techniques like eye movement tracking for example. This technique has been applied successfully to measuring driver distraction, e.g. by counting how often the driver watches the speedometer or the rear-view mirror. The treatment of an emergency patient, however, represents a more complex situation so that we would not be able to judge on SA just by tracking the eye movements when watching the patient and the monitors.

Out of all known survey techniques, the Situation Awareness Global Assessment Technique (SAGAT) (Wickens 2008b) has been used most frequently for measuring SA. It has been classified as an objective offline technique and it works in such a way that a subject undergoes a simulation setup that stops at a random moment. Then, the subject is asked a

few questions regarding the three levels of SA as mentioned above. The given answers are compared to the simulated data in order to determine the subject's instant SA (Endsley 1995a). Obviously, SAGAT is applicable only to simulated, but not to real-life situations. This is in contrast to a second technique: The Situation Present Assessment Method (SPAM) is an objective, but online measuring method. It is applicable both to simulated and actual situations: Without freezing the situation, the subject performs the work as usual and at any moment is asked questions related to the three levels of SA. SA then will be assessed by measuring the time needed by the subject to react to the questions and to find the right answers in the current setting, e.g., by evaluating the monitors (Loft, Morrell et al. 2013). Apart from these two, a third technique has been widely used: the Situation Awareness Rating Technique (SART) by Taylor (1990). It is regarded a subjective technique measuring ten attributes that are classified into three major dimensions: *demand on attentional resources*, *supply of attentional resources* and *understanding*. After the end of the simulated or actual situation the subject fills in a form by marking numbers from 1 to 7 for each of the 10 attributes. The single scores add up to the SA score (Taylor 1990). As a matter of fact, SART is a widely known and well-established subjective rating technique, though it does not use the three levels of SA proposed by Endsley (1995b). It has been criticized for mixing up SA levels with dimensions of attentional resources and workload (Endsley and Garland 2000).

For this present study we use an adapted subjective rating technique based on the three levels of SA (Endsley 1999). It was adapted to German language by Arpe (2013).

1.3.3. Situational Awareness in Emergency Medicine

Originally, the concept of SA was introduced and adapted to military and civil aviation (Endsley 1988, Hartman and Secrist 1991). Gaba, Howard et al. (1995) were among the first to apply the concept to a medical environment. Indeed, judging from SA relevant aspects, typical situations in a cockpit might resemble typical situations in several medical domains: When it comes to critical situations both environments are characterized by fast changing dynamics with potentially lethal outcome as well as by the demand to handle complex systems that require to be understood and eventually repaired within a short period of time, just to name a few commonalities. By analyzing a number of critical incidents in

anesthesiology, Gaba, Howard et al. (1995) found out that many mistakes resulted from human factors and they further concluded that SA needs to be trained during residency.

Among others, Blandford and William Wong (2004) were the first to apply the concept of SA explicitly to situations in emergency medicine. Using observation and interview techniques they analyzed the process of decision making in a rescue coordination centre: Their study described how the staff of a rescue coordination centre developed a *mental picture* out of the caller's report. Inputs they used to draw that *mental picture* were e.g., the relative location of hospitals or ambulance stations and the current availability of ambulances. Here from, they allocated the necessary actions, e.g., ordering an additional ambulance or a helicopter. Thus, the authors showed the importance of a high SA when it came to take the right and potentially lifesaving decisions. Besides, they also showed that many different factors influenced the quality of SA. For instance, they observed that more experienced allocators were able to draw their *mental picture* faster and more precisely with even less information. So, based on the same input (Level 1: perception), the ability to interpret this information (Level 2: comprehension) and to develop an appropriate image of the future (Level 3: projection) depended heavily on the experience of the allocator (Blandford and William Wong 2004). Obviously, it takes much time to build up experience for a young resident or a young nurse. Furthermore, we would like to identify other factors that contribute to provider's SA.

Zhang, Drews et al. (2002) also reported on the importance of a SA in a medical environment such as anaesthesiology. They analysed the SA with respect to intraoperative monitoring using different techniques to visualize the patient's vital signs. They found that a significant change of vital signs was detected by anaesthesiologists most quickly, if they used 3D animation monitoring. Of course, good monitoring design is unlikely to be the only variable influencing SA crucially.

Summing up, SA has widely been investigated in aviation and, later on, it was adopted to other occupational settings. In particular, there are a few publications on SA in anaesthesiology. Systematic and comprehensive research on SA in ED, however, is still lacking, especially when it is about addressing patients' safety.

1.3.4. Hypothesis

Given the results of research on SA in branches outside of EDs, we assume good SA can reduce errors and avoid critical situations. Parameters leading to good SA in an ED context are still little investigated. We are willing to further investigate the influence of MT and Stress on SA in order to find ways to better understand the ED and improve patient safety.

1.4. Objectives

Using a multi-source study in a German interdisciplinary ED we sought

1. to determine the overall ratio of MT in ED providers as well as per ED profession,
2. to determine the overall level of SA as well as per ED profession, respectively, and
3. to investigate associations between MT and SA per ED profession and to explore their potential relationships with providers' stress levels.

2. Methods

2.1. Design

Our study used a mixed-methods approach applying both standardized observations and a questionnaire: ED providers (physicians and nurses) were observed at work by trained observers and surveyed for their self-perception immediately afterwards. The observation period lasted for 90 minutes, and dimensions covered by the questionnaire were self-perceived SA, MT, and stress levels.

This study forms part of a research program on ED providers' working conditions and the quality of delivered care (Schneider, Wehler et al. 2019). ED staff was informed about these investigations verbally and in written form. The information was provided during departmental meetings and was also presented in newsletters distributed to ED staff. Participation in this study was kept voluntary for ED staff, and participant's consent was obtained prior to each single observation unit. The study was approved by the Ethics Committee of the Medical Faculty of Munich University (NR 327-15).

2.2. Setting

Our study took place in the interdisciplinary ED of a major metropolitan academic medical centre with approximately 78.000 visits per year. The ED is open 24 hours every day. It is staffed continuously with clinicians, nurses and assisting personnel. It can be considered as one of the biggest interdisciplinary EDs in Germany with regard to size, number of patients, work organisation, staff and medical equipment. This ED forms an independent department within the hospital and it relies on its own administration. Staff includes the head of department, senior, specialists and junior physicians (undergoing specialty training), nurses, and rotating residents. As Emergency Medicine is not a recognized specialisation in Germany, this ED is run by physicians who originally specialized in internal medicine, trauma surgery, anaesthesiology, and other specialisations.

This ED splits into three different ED treatment areas: there are examination rooms for (1) internal and (2) trauma patients and (3) an observation and clinical decision unit, where patients can be hospitalized up to 24 hours for comprehensive diagnostics and initiation of appropriate treatment so as to shorten the overall duration of their stay in hospital.

2.3. Sample

This study covers both major ED professions: (1) physicians (senior, specialist and resident physicians) and (2) nurses. Medical or nursing students were not included.

Our study was scheduled for 80 observations with a duration of 90 minutes each. All observation sessions were conducted on altogether 20 days and sessions were randomly assigned to weekdays and weekends; only during day shifts between 8:00 am and 5:00 pm. The observations were randomly assigned to the three different ED treatment areas and the different ED professions. In order to maximise objectiveness and to minimize observer effects (i.e., Hawthorne effect), expert observers did not take part in patient care, they were not involved in decisions on treatment, and they did not actively initiate conversations with members of ED staff.

2.4. Observation procedure – example

Having explained the aims of the study and obtained consent by the subject, the observer shadowed the ED provider for 90 minutes: all observed tasks were recorded continually based on an event coding approach, i.e., each change of tasks was registered as primary task with task category code and time stamp. Task category code (see below, **Table *1***) and time stamp (with hour, minute, and second - read from a wristwatch timer) were noted by the observer on a clipboard. Simultaneously performed tasks were recorded in the same line as primary and secondary task, respectively. Subjects were selected in such a way so as to avoid shift changeover within the observation time of 90 minutes. After the end of the observation, the ED provider was asked to immediately fill in the questionnaire. Indeed, in the majority of requests, the completed form was returned to the study team within a few minutes after the end of the observation period. In all cases, however, we received the completed questionnaire within the same day.

2.5. Measures

2.5.1. Observational measures

During the observation period, the observer recorded every primary task performed by the observed ED provider. For that purpose, we used an observational tool that was developed for the identification of clinician activities in hospitals and has been repeatedly applied in previous studies (Weigl, Müller et al. 2009). ED provider tasks are classified into eleven

categories (**Table *1***) which are clustered into the following four overall activities: direct patient-related tasks, tasks with indirect patient-relation, teaching and supervision and personal activities (Weigl, Müller et al. 2009).

Whenever the observed provider was performing more than one task simultaneously (e.g. when talking to the patient whilst taking notes) the observer recorded a MT activity. The task that was still ongoing when a second task was initiated was regarded to be the main task and therefore it was named *primary task* while the second task was named *secondary task*.

Table 1. *ED providers' task categories*

Task category	Description
Direct patient-related tasks	
1 Patient/ Relatives communication	Direct communication with a patient or relatives (e.g. admission interview, consultation, informal consent, discharge instructions, small talk)
2 Diagnostics	Performing clinical diagnostics (e.g. examination, ECG, taking a blood sample, measuring pulse/blood pressure)
3 Therapy	Medication, laceration closure, patient transfer
Tasks with indirect patient-relation	
4 Consultancy	Consultancy with colleagues/specialists about diagnostical and therapeutical management
5 Documentation/ Charting	All kind of paperwork (e.g. charting, appraisal, letter writing)
6 Communication with ED staff	Patient-related conversation with ED colleagues
7 Communication with other staff	Telephone conversations, patient-related conversation with external colleagues (e.g. paramedics)
8 Organization/ Workflow	Organization, workflow, instrument repair (e.g. staff roster, ordering stocks, maintenance)
9 Meetings (regular/ irregular)	Scheduled and irregular meetings (e.g. shift changeover, conferences)
Teaching/ Supervision	
10 Teaching/ Instruction/ Supervision/ Research	Teaching of students or younger colleagues with knowledge transfer, research, reading up on internet or a book
Personal activities	
11 Personal Activities/ Breaks	Eating, hygiene, small talk

Notes Source (Weigl, Beck et al. 2017)

2.5.2. ED provider questionnaire

After each observation session, the observed ED provider was asked to fill in a short questionnaire covering the following provider outcomes:

- **Self-perceived Multitasking**: This question assesses the frequency of multitasking demands during the observation period as perceived by the subject. It was measured with just one question taken from a work analysis tool (ISTA) that is well-established in Germany: "How often did you have to work on tasks simultaneously?". The answers were recorded on a visual analogue scale from 0 ("few") to 10 ("very frequent") (Semmer, Zapf et al. 1999).
- **Situational Awareness**: ED provider's Situational Awareness during the observation was determined using a simplified scale based on the three levels of SA as described above (Endsley 1995b, Arpe 2013). The items have been previously used in German language and applied to a study within a healthcare provider sample (Arpe 2013). The following wording reflects the three levels of SA:
    - (1) perception: "I was able to *perceive* information important for my task."
    - (2) comprehension: "I was able to *comprehend* important information regarding my task."
    - (3) projection: "I was able to anticipate future developments resulting from my efforts."

  All items were answered using a visual analogue scale from 0 ("not at all") to 10 ("yes, entirely"). These three results were aggregated to a mean score, called SA scales' mean. Internal consistency as calculated according to Cronbach's Alpha (CA) was 0.70 (n=74).
- **Provider stress**: Following the well-established STAI-6 scale, we investigated three aspects of ED provider's work-related stress during the observation: cognitive, emotional, and physical (Marteau and Bekker 1992). The result is the mean of the assessments for 6 adjectives (e.g. "calm", "upset"), with possible answers ranging from 1 ("not at all") to 4 ("completely"). This scale also showed satisfactory internal consistency with CA=0.68 (n=79).

2.5.3. Additional data for the characterization of ED workload

Besides the parameters mentioned so far, we also considered other causes for increased workload in ED, namely an inappropriate ratio of patients versus staff: Patient load, number

of physicians, number of nurses and number of urgent patients are commonly seen as relevant factors that determine ED workload. In order to take into account these **process parameters**, in addition to the parameters mentioned above, we also recorded

(1) the total number of patients in the ED at the time of the observation,

(2) the number of the colleagues of the same profession being present in the ED during the observation, and

(3) the number of highly urgent (ESI 1 and 2) patients, based on triage data using the emergency severity index (Eitel, Travers et al. 2003).

2.6. Statistical analyses

All data were transferred into our database and double-checked for consistency. All observational data were additionally coded for ED professions and ED treatment areas. We calculated the total time of observation, the total time of each observed task and the ratio of MT in total and subdivided by the ED professions and the ED treatment area. In order to determine associations between self-perceived and observed MT across all observation sessions, we applied linear correlations. We correlated providers' aggregated responses of the corresponding questionnaires with the observed MT ratio; calculated both from the total time and the total number of performed MT. To determine group differences between both ED professions, analyses of variance tests were applied to the survey data; that compared the values for different ED professions and ED treatment areas via one-way ANOVAs. Finally, linear regression analyses were applied to determine associations between the observed MT and provider outcomes (Perceived MT, SA, Stress). Moreover, we also sought to identify associations between ED workload data and the provider outcomes. Significance was considered with $p < .05$. All statistical analyses were computed with SPSS 24.0 (IBM Inc., Chicago).

3. Results

3.1. Observational results

We observed ED providers for a total of approximately 120 hours, equivalent to a total of three weeks of eight-hour shifts. Thereof, ED nurses were surveyed for a total of 73 hours (61.2 %) and ED physicians for a total of 46 hours (38.8 %) (***Table 2***, for full set of data see Appendix, ***Table 13***).

We identified a total of 5,013 tasks during 80 observation sessions or 120 observation hours resulting in 42 tasks per hour on average. The average duration of an observation session was M = 1:29:38 hours (SD=0:02:52, range 1:18:57-1:36:00). The average duration of one task was 1:26 minutes.

The most time-consuming tasks performed by the ED providers for all ED professions were Therapy (3), Documentation/ Charting (5), and Communication with ED staff (6). For nurses, therapeutic activities (3) were observed for most of the time, whereas physicians were recorded to stay more involved in Documentation/ Charting (5). Again, Organization/ Workflow (8) related activities took a bigger share of nurses' time (***Table 2***, ***Figure 1***).

Table 2. ***Observed task ratios (time) in ED: primary tasks in total and per ED profession***

observed tasks	primary tasks (total)	primary tasks (nurses)	primary tasks (physicians)
1 Patient/ Relatives communication	7.9%	5.8%	11.1%
2 Diagnostics	9.9%	9.4%	10.6%
3 Therapy	18.6%	27.3%	5.0%
5 Documentation/ Charting	19.0%	12.0%	30.0%
6 Communication with ED staff	17.0%	17.0%	16.9%
7 Communication with other staff/ Telephone conversations	6.6%	5.1%	8.9%
8 Organization/ Workflow	13.6%	17.5%	7.4%
Others	7.6%	5.9%	10.1%
Total (%)	100.0%	100.0%	100.0%
Total (hours)	119:31:29	73:10:58	46:20:38

Note for full set of data see ***Table 13***

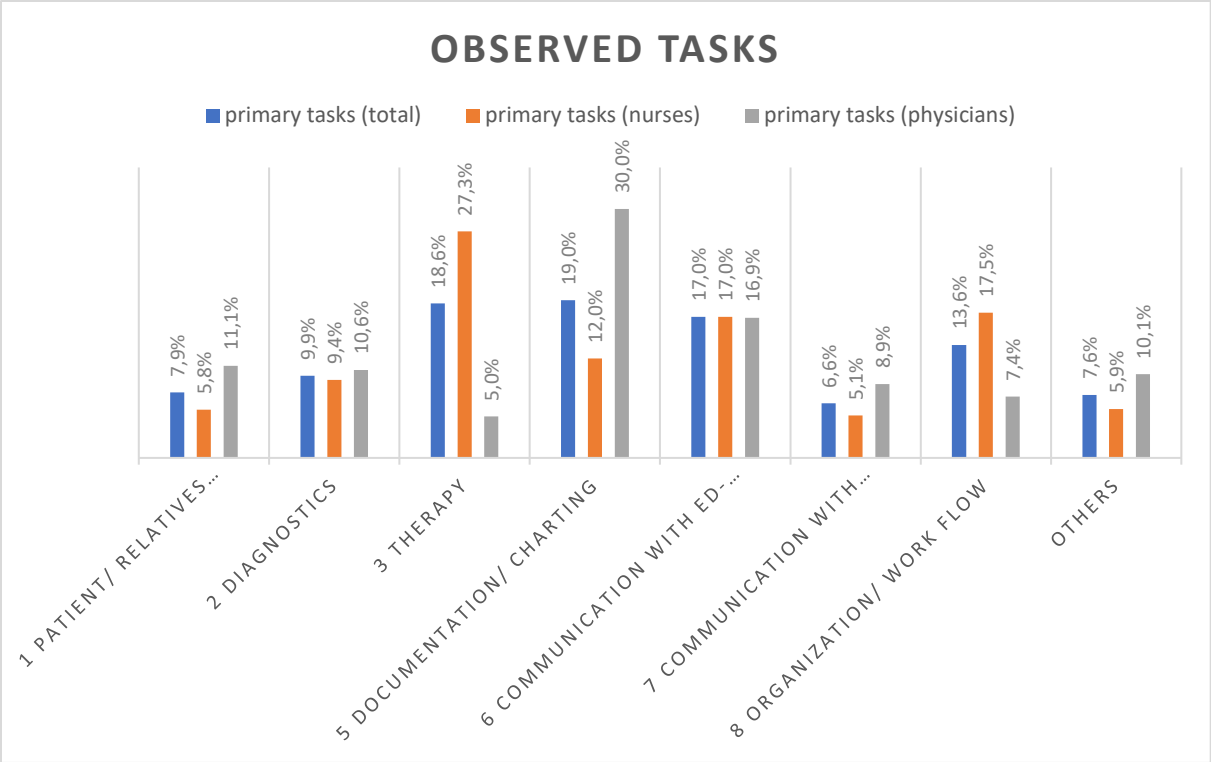

Figure 1. ***Observed Task ratio in ED: primary tasks in total and per ED profession (Table 2)***

3.1.1. Multitasking activities

We recorded 628 events where a secondary task was performed in parallel to a primary task. These situations made up for a total of approximately 12 out of 120 hours. These situations were identified as MT. This resulted in a MT ratio of 10.4% out of the total observation time, meaning that ED providers performed MT for approx. 6 minutes per hour. Looking at each ED profession separately, physicians were multitasking for 13.0 % of the observed time, nurses for 8.7 %.

Two task categories were found to form part of a MT situation for more than 20% of total MT time – be it as primary or secondary task: these were Patient/ Relatives communication (1) and Documentation/ Charting (5); (see ***Figure 2***).

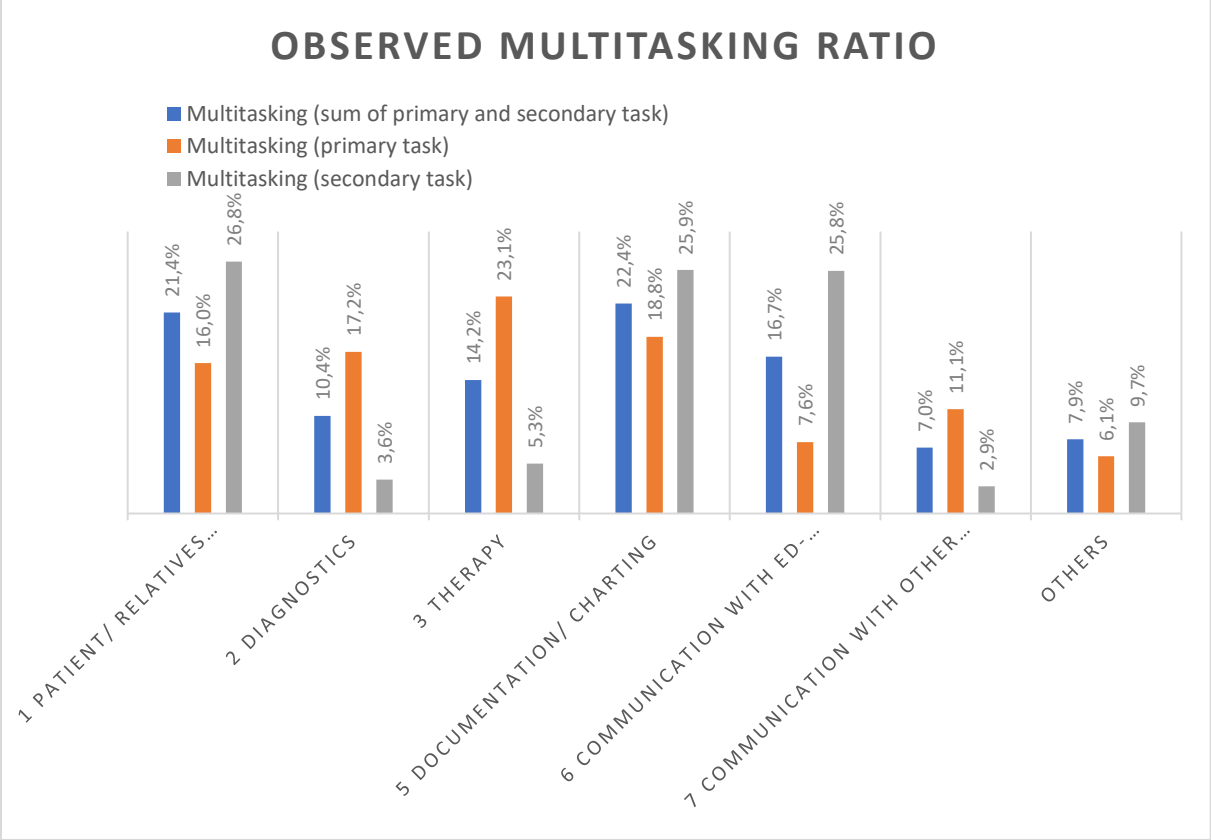

Figure 2. ***Observed MT ratio (as primary or as secondary task) in ED: MT ratio of the sum of primary and secondary tasks for each task category, total = 119:31:29 hours (for full set of data see Table 14)***

Obviously, for situations of MT, some tasks were found to occur more frequently as primary task and others showed an increased likelihood as secondary task. Out of all observed MT situations, Therapy (3) made up for 23.1 % of total time for primary tasks, but only 5.3 % of total time for secondary tasks, and, on the other hand, Patient/ Relatives communication (1) took a share of 16.0 % in primary tasks, but of 26.8 % in secondary tasks (***Figure 2***).

Concerning the combinations of tasks during the observed MT workflow situations, ***Table 3*** depicts the most frequently observed combinations of primary and secondary activities of ED providers.

Table 3. *Task combinations in MT situations, for full set of data see Table 15*

Primary task	&	Secondary task	Ratio
1 Patient/ Relatives communication	&	5 Documentation/ Charting	9.1%
2 Diagnostics	&	1 Patient/ Relatives communication	11.1%
3 Therapy	&	1 Patient/ Relatives communication	10.2%
3 Therapy	&	6 Communication with ED staff	10.2%
5 Documentation/ Charting	&	6 Communication with ED staff	10.2%
7 Communication with other staff/ Telephone conversations	&	5 Documentation/ Charting	8.0%
other combinations			41.0%
Total			100.0%

3.2. Questionnaire results

For each of the 80 observation sessions, we received a valid questionnaire on self-perceived MT and stress levels. As to providers' SA assessments, we obtained 74 valid questionnaires, as six survey printouts erroneously did not use the correct SA scale.

3.2.1. Self-assessment of stress level

After each observation session, the observed ED provider rated the experienced stress level using the STAI stress scale with a minimum stress level of 0 and a maximum stress level of 4. Altogether, the mean stress level was M = 1.96 (SD = 0.49, range 1-3.17) with no significant difference between both ED professions: F(1, 78) = 0.01, p = 0.92 (**Table *4***).

Table 4. *Self-assessed stress levels*

STAI scale	N	M	SD
nurses	49	1.95	.07
physicians	31	1.97	.09
total	80	1.96	.05

Notes STAI stress scale consists of 6 items merged to the mean, N (number of valid questionnaires), M (Mean, range 1-3.17), range of scale 0-4, SD (standard deviation)

3.2.2. Self-assessment of Situational Awareness

Merging three questions based on the three levels of SA into a mean SA score, we obtained a mean SA of 7.1 out of 10 (SD = 1.5, range 3.3-9.5, ***Table 5***) with no significant difference between both ED professions: F(1, 72) = 0.52, p = 0.47.

Table 5. ***Self-assessed SA levels***

SA	N	M	SD
nurses	46	7.20	1.37
physicians	28	6.94	1.66
total	74	7.10	1.48

Notes SA (Situational Awareness), N (number of valid questionnaires), M (Mean), range of scale 1-10, SD (standard deviation)

3.3. Comparison of observed and self-perceived Multitasking activities

We observed an overall MT ratio of 10.4%. Also, after each observation session, the observed ED providers assessed their self-perceived MT demand level (on scale from 0-10). The overall mean was M = 4.66 (SD = 2.62, range 0.50-9.50). For both professions, the self-perceived MT averaged on a similar level between 4 and 5, with F(1, 78)= 0.43, p= 0.51 (***Table 7***).

Table 6. ***Observed and self-perceived Multitasking levels***

	observed					self perceived	
MT	**N**	**time**	**N (MT)**	**time (MT)**	**MT ratio (time)**	**M**	**SD**
nurses	3199	73:10:58	353	6:22:31	8.71%	4.82	2.71
physicians	1814	46:20:38	275	6:02:20	13.03%	4.42	2.51
total	5013	119:31:00	628	12:24:51	10.39%	4.66	2.62

Notes MT (Multitasking), N (number of observed tasks), N (MT) (number of observed MT), M (mean, range 0-9.5), SD (standard deviation)

Correlating the observed MT ratio for all observation sessions (in % of observation time) to the self-perceived MT level as reported by the observed provider after the observation session, we found no significant correlation: r=0.182, p=0.105. However, a significant correlation was found between the number of observed MT activities (N) per session and the self-perceived MT: r= 0.258, p= 0.021 (see **Table *7***).

Table 7. ***Association between observed and self-perceived Multitasking***

	self perceived MT		MT number	
linear correlation	**r**	**p**	**r**	**p**
self perceived MT			0.258	0.021
MT ratio (time)	**0.182**	**0.105**	**0.873**	**<.01**

Notes MT (Multitasking), r (Pearson correlation coefficient), p (p-value)

3.4. ED workload data

We also recorded ED workload data as objective parameters. The mean number of patients who were present in the ED during the observation sessions was M = 44.4 (SD = 33.8, range 9-99), the mean number of colleagues (of the same profession) on duty in the observed area was M = 18.4 (SD = 1.2) for nurses and M = 10.9 (SD = 1.9) for physicians.

The average number of highly urgent patients (ESI 1 and 2) for the whole day of the observation was M = 22.34 (SD = 4.36, range 17-35).

3.5. Multivariate analyses

In this step, for all observation sessions, we sought to identify associations between ED workload data and observed MT time ratio to the self-assessed stress level on the one hand and to the self-assessed Situational Awareness on the other hand.

3.5.1. Workload data and stress level

As to the process parameters, we found that the number of patients had a significant influence onto the stress level of nurses (β=0.322, p=0.023), but not of physicians (β=0.052, p=0.793, **Table *8***). However, regression showed a positive influence of the number of high-risk patients onto physicians' SA (β=0.409, p=0.024, ***Table 9***).

3.5.2. Multitasking ratio and stress level

Concerning observed MT and self-perceived stress level, there was no significant correlation (**Table *8***).

Table 8. ***Influence of workload and Multitasking on the ED providers' stress assessment – by professions***

	ED profession					
	total		nurses		physicians	
Determinant	**β**	**p**	**β**	**p**	**β**	**p**
high-risk patient ratio	.208	.068	.254	.071	.215	.28
number of patients	.222	.051	**.322**	**.023**	.052	.793
number of colleagues	-.016	.889	.264	.064	-.111	.569
MT time ratio	-.083	.473	-.063	.642	-.147	.454

Notes ED (emergency department), MT (Multitasking), β (standardized regression coefficient), p (p-value)

3.5.3. Multitasking ratio and Situational Awareness

In this step we computed associations for ED workload data, the observed MT, and provider SA. Overall, for all ED providers, we found no significant influence of MT on SA (β = 0.157, p = 0.204). However, for physicians alone, we found a significant correlation of observed MT ratio and self-assessed SA (β = 0.473 p = 0.009) (see ***Table 9***). Furthermore, when differentiating for the three levels of SA (i.e., for each SA item individually), we found a strong influence of observed MT ratio on the third level of SA, namely projection (β = 0.478, p = 0.006) (***Table 10***), for the group of all ED providers.

Table 9. ***Influence of workload and Multitasking on Situational Awareness – by ED profession***

	ED profession					
	total		nurses		physicians	
Determinant	**β**	**p**	**β**	**p**	**β**	**p**
high-risk patient ratio	.022	.856	-.260	.093	**.409**	**.024**
number of patients	-.167	.161	-.175	.245	-.124	.468
number of colleagues	.142	.244	-.197	.202	.292	.090
MT time ratio	.157	.204	-.091	.541	**.473**	**.009**

Notes ED (emergency department), MT (Multitasking), β (standardized regression coefficient), p (p-value)

Table 10. ***Influence of workload and Multitasking on Situational Awareness – by each SA item***

	SA question total SA scale		1 perception		2 comprehension		3 projection	
Determinant	**β**	**p**	**β**	**p**	**β**	**p**	**β**	**P**
high-risk patient ratio	.022	.856	.304	.133	.329	.090	**.411**	**.018**
number of patients	-.167	.161	-.101	.607	-.197	.299	-.053	.742
number of colleagues	.142	.244	.120	.538	.183	.325	**.394**	**.020**
MT time ratio	.157	.204	.351	.081	.376	.051	**.478**	**.006**

Notes ED (emergency department), MT (Multitasking), β (standardized regression coefficient)

3.6. Data from different ED treatment units

In addition to analysing the questionnaires by profession, we also differentiated by ED treatment areas (refer to chapter 2.2) applying a single-factor analysis of variance. Comparing the answers for the three different areas no significant difference became apparent with only one exception: the SA question level on comprehension (item 2) came out with $F(2, 71) = 3.37$, $p = 0.04$. However, as a matter of fact, the post-hoc analysis (Scheffé procedure) showed only a nearly significant difference for that same question when comparing the internal unit to the observation and clinical decision unit (mean difference: 1.13, 95%-CI[-2.27, 0.02], $p = 0.054$).

4. Discussion

Drawing upon a multisource study in a German interdisciplinary Emergency Department (ED) we sought to

1. determine the overall ratio of multitasking (MT) by ED providers and per ED profession,
2. assess the overall level of Situational Awareness (SA) for ED providers and per ED profession, respectively, and
3. detect possible correlations between MT and SA of ED providers as well as to explore the influence of MT on the stress level of ED providers.

When discussing the role of MT in occupational environment, previous studies suggested that stress has a negative impact on SA (Endsley 1995b, Sneddon, Mearns et al. 2013). So far, however, there has been no empirical evidence based upon observational studies in real-world EDs. Therefore, this multi-source study explored a combination of empirical techniques and investigated the relationships between MT, SA and stress for ED providers in a German interdisciplinary ED.

4.1. Multitasking in the Emergency Department

Recent studies reported on ED physicians' MT ratios in the range of 7.4 % to 30.6 % of total work time (Chisholm, Dornfeld et al. 2001, Asaro 2004, Edwards, Fitzpatrick et al. 2009, Weigl, Müller et al. 2009, Westbrook, Coiera et al. 2010, Mache, Vitzthum et al. 2012).

Remarkably, only two studies investigated profession-related differences. Edwards, Fitzpatrick et al. (2009) measured a MT ratio of 14.8 % both for physicians and nurses. Coiera, Jayasuriya et al. (2002) analysed to which extend physicians and nurses performed more than one overlapping conversation and found physicians to perform MT in 14.6 % and nurses in 6.7 % of total communication time.

Our study determined MT ratios of 13.0 % for physicians and 8.7 % for nurses. An explanation for this difference could be that – according to our observations – physicians spent more time on Documentation/ Charting activities than nurses. Likewise, according to our results, Documentation/ Charting activities were the most common tasks that were performed in MT situations. Interestingly enough, both nurses' and physicians' groups reported similar levels of MT, when they were asked for their self-perception. As a matter of

fact, most ED providers were rather surprised when they learned after the observation session for how much time they had been multitasking. Nonetheless, the study showed a correlation between counts of observed MT activities per session and the self-perceived MT in terms of how often MT had been performed. This suggests that ED providers' perception actually corresponded to some extent to the observer's records on how often a secondary task was started in parallel to a primary task.

On the other hand, we found no evidence of any significant correlation between total time of observed MT activities and self-perceived MT level. This suggests that ED providers' perception was not so much influenced by the total time where multiple tasks were performed simultaneously, but more by the frequency of MT activities. It further spurs the question if the mere occurrence of multitasking is more salient to provider's subjective perception of multitasking than the actual duration of concurrent activities. Nevertheless, in accordance with the majority of studies on MT in terms of concurrently performed tasks, this study primarily uses the MT time ratio for statistical evaluations. Nevertheless, we performed the statistical calculations also for the MT count numbers: As a matter of fact, the statistical results came out less significant (***Table 11***, ***Table 12***).

Adams and Rho (2016) showed that the biggest challenge for scientific investigations on MT was to identify reliably those situations where MT started to become hazardous to performance and quality. So, it seemed interesting to find out how this challenge was being dealt with in real life.

Similar to earlier findings (Asaro 2004), we observed that certain combinations of activities accounted for a bigger share in MT situations than others: e.g., Patient/ Relatives communication paired with Documentation/ Charting and Diagnostics with Patient/ Relatives communication (cf. ***Table 3***). It was of particular interest that ED providers combined activities of Diagnostics or Therapy less often with a second task. Presumably, be it knowingly or unknowingly, they considered these activities as more incident-sensitive than others like talking with patients, relatives or colleagues. Documentation/ Charting, on the other hand, is one of the most commonly used MT activities. Post-hoc, this observation may suggest that the observed documentation activities merely required additional input by patients or ED staff for their completion and, in addition, were not considered as incident-sensitive activities.

Skaugset, Farrell et al. (2016) considered MT as a key skill for efficient emergency treatment and proposed that MT should be included systematically in ED providers' training. On the other hand, the same authors claimed that – for the sake of security – MT should only be performed in parallel to simple routine jobs (Skaugset, Farrell et al. 2016). This would mean that the single task needed to be trained up to the level so as to enable automated (quasi subconscious) performance.

In the late 80's, Wickens developed the theory of multiple resources: he pointed out that different tasks interfered with each other all the more if they relied upon the same mental, sensorial and neurophysiological resources (Wickens 2002, Wickens 2008a). Wickens explained, how the likelihood of a given combination of multiple and concurrent tasks depended upon the extent of the utilization of common modalities or resources. With regard to our observations, we assume that combinations of concurrent documentation and communication tasks may be favored for the reason that they rely on different resources, i.e., visual vs. auditory, spatial vs. verbal etc. Yet, activities like diagnostics need close attention of mental resources and high levels of cognitive resources for decision-making. Thus, they do not go well together with other tasks that call for the same resources. Obviously, future studies on MT in Emergency Medicine need to investigate these assumptions by testing specific task combinations in more detail, i.e., in laboratory as well as real-world clinical settings.

4.2. Situational Awareness in the Emergency Department

Situational Awareness describes the ability to cope with the demands of obtaining the right information, of interpreting it in a correct way and of deducing the right decisions – and all of that possibly under time pressure.

Obviously, by self-assessment, it is difficult to judge whether the right information was perceived and interpreted: for instance, information that was missed to retrieve cannot help to deduct the appropriate conclusions. To overcome this risk, it is compulsory in aviation for example to complete the respective checklist prior to safety-relevant manoeuvres. Checklists also help to ensure that no important information gets lost during handover procedures due to failures in attention (Gaba, Howard et al. 1995). Also, ED providers are at risk to miss relevant information with fatal consequences: for example, if ED providers did not measure the level of blood glucose in an unconscious patient, the loss of consciousness might be

falsely attributed to cardiac origin. However, it could also result from low (or even high) level of blood glucose. Therefore, also for ED processes, instructions are being used. However, once a patient becomes unconscious, there is no time to tick checklists.

Potentially, future technologies will enable providers to follow process instructions in parallel to work, for example, with a simple algorithm that communicates live via automated speaking devices, i.e., robot similar to the heart defibrillator that is able to interpret the electrocardiogram in real time and, if appropriate, to recommend an electric shock verbally. So, in future EDs, a smart computer speaker might be part of every patient contact: Every reported symptom and every measured parameter might be analysed and fed into the algorithm to come up with recommendations on what to do next. However, potential effects for situation awareness, provider's cognitive load, as well as decision making need to be scrutinized before implementation. Indeed Gaba, Howard et al. (1995) proposed to specifically train SA by making subjects familiar with the diagnostic equipment in order to speed up the identification of critical situations, their cause and their meaning.

4.3. Influence of Multitasking on Situational Awareness

Ophir, Nass et al. (2009) reported interesting findings as to the interrelation of MT and task switching: media multitaskers who heavily used smartphones and laptops in parallel to work or other activities showed reduced ability to filter irrelevant from relevant information and higher likelihood to be distracted when undergoing standardized task switching tests. Later on, Lin (2009) as well as Jorm and O'Sullivan (2012) reinterpreted these results by assuming that heavy media multitaskers might perform a better SA because of their "trained" ability to collect much more information simultaneously from their environment.

We found in this study that physicians who had been observed to perform more MT reported higher levels of SA statistically. Moreover, we detected a strong association between MT ratio on the third facet of SA, i.e., projection.

These findings may be surprising at first sight. We assume post-hoc that frequent MT enables physicians to gather relevant information within an appropriate time and to achieve higher situational awareness during their clinical work – at least in their own judgement. Thus, our findings may suggest that regular use of MT and even the training of MT in less

complex situations can contribute significantly to the subjective impression of maintaining high cognitive awareness in stressful clinical situations.

Furthermore, we found physicians indicating a higher SA on days with higher number of high-risk patients. Apparently, in critical situations physicians realized that their utmost attention was required in order to obtain all relevant information – from different sources, i.e., the report of the emergency physician during the handover, the examination of the patient or vital signs – eventually, in order to draw the right conclusions and to make lifesaving decisions.

For nurses, on the other hand, our results hint to a – non-significant – negative influence of a higher number of high-risk patients on SA. This may be interpreted as nurses perceive higher likelihoods of losing control in critical situations, i.e., higher numbers of critical patients to care for. We speculate that it might result from the fact that in critical situations usually the team leader manages to maintain oversight on the overall situation, supervises and provides instructions to the team and it individual members who primarily focus on individual patients. In these situations, the nurse's function primarily includes executing single tasks with high accuracy (e.g. insertion of a venous access), while physicians usually assume the role of the team leader.

4.4. Stress load in the Emergency Department

Some authors commented on stress-related safety issues in the ED as described above (cf. 1.2). They highlighted in particular the importance to train ED providers how to cope with mental pressure in order to prevent stress and potentially risky consequences: Wetzel, Kneebone et al. (2006), Wetzel, Black et al. (2010) showed the importance of learning efficient coping strategies so as to successfully manage stressful situations and to reduce the risk of incidents.

A key question of this study was to which extent MT is associated with ED provider's mental stress load. Notably, our results did not produce empirical evidence that MT influences ED providers' self-perceived stress levels.

Furthermore, there were reports on other factors contributing to ED provider's stress level: Mostly mentioned among negative factors were high workload, staff shortage and the impossibility to perform freely within a supportive environment (Burbeck, Coomber et al.

2002, Flowerdew, Brown et al. 2012, Basu, Qayyum et al. 2017). Indeed, we found a significant reduction of the reported stress levels of nurses during observation sessions with fewer patients to be looked after in the ED.

Obviously, the design of our study was not meant to investigate the effects of staff shortage, as staffing was relatively stable during the period of our observations. And, indeed, the data did not show influences on stress levels within the slight variations of staffing numbers.

One of the observed ED providers shared his insight that every complex task like taking a blood sample, writing an electrocardiogram or writing a medical report consisted of multiple single steps that needed to be performed one after the other. Such work could easily be performed as long as there was no interruption. However, it became stressful whenever the ED provider was hindered to complete the workflow and compelled to resume it a few instances later – with the latent risk in mind of missing important steps. Indeed, Weigl, Beck et al. (2017) found increased stress levels among ED providers who had been interrupted incidentally while working on a specific case, if the interruption resulted from a parallel case within the responsibility of the same ED provider. Remarkably, some authors define MT as being responsible for several cases at the very same time (Chisholm, Collison et al. 2000). With this in mind, it might be concluded that MT increased the individual stress level, if it occurred accidentally so as to preclude the subject from finishing an already started workflow due to an unexpected incidence within the subject's area of responsibility.

As our statistical results do not support a significant influence of MT on stress levels, it seems possible that a considerable share of the recorded MT events were induced intentionally by the ED provider in order to finish a work sequence of logically fitting tasks, i.e., additional information was needed from the patient in order to complete the documentation. If, however, MT combinations were effected voluntarily by ED providers, it seems obvious that they did not expect potential safety risks from these MT situations. And this perception might explain why they did not feel stressed by the occurrence of these MT situations.

In contrast, those task combinations that were observed less frequently might have been avoided by ED providers whenever possible because they judged them as potentially risky. In turn, duration and/or frequency of those presumably undesirable MT combinations might correlate to ED providers' self-perceived stress levels.

Therefore, future studies might focus on externally prompted MT combinations within even larger data sets of concurrent clinical activities.

5. Limitations

It goes without saying that the most important question of doing research is about relevance. We were interested in measuring MT in an ED in order to finally contribute to the crucial question whether performing MT increased the risk of errors in EDs. For a number of good reasons, however, it seems very difficult to generate valuable data to resolve this question. Due to the complexity of cases in acute care, it is far more difficult to count medical errors in a running, real-world clinical system than counting errors in a pure test environment or even during driving a car. As a matter of fact, it seems very hard to comprehensively identify and validate errors in an ED's daily operations: First, mistakes do not usually become apparent immediately but only after a while or even do not appear at all. Second, observers need to be professional in the specialty they observe in order to be in a position to detect mistakes immediately. Third, upon identification of an error, the observer would have to intervene in order to safeguard patient's care. This interruption would profoundly influence the results of the study. And finally, there is an intrinsic problem with recording mistakes in real situations, as observed subjects will feel under considerable pressure to avoid being caught with any mistake. This will not only influence the results, but also might make it difficult to obtain consent for such an observational study. Kalisch and Aebersold (2010) deployed trained nurses to observe other nurses doing MT and being interrupted during their work. They recorded different patterns of errors, e.g. missing to wash hands or not wearing gloves or even confusing medication.

In their systematic review Douglas, Raban et al. (2017) reported several possibilities to avoid counting mistakes by measuring alternative parameters, e.g. time for handover, self-reported performance level or lack of recalling previous information. In clinical practice, the proposed parameters are unfortunately often difficult to measure, so that validity and reliability remain questionable. So, in order to investigate the relation between MT in EDs and the risk of errors, a feasible approach seems to transfer findings from simulation settings to real-world clinical care.

We decided to undertake an empirical study in a real ED and, within the given limits for our study, purposely did not watch out for mistakes, but focused primarily on the observation of activities and the assessment of self-perceived parameters. The logical consequence was that from our study we could not comment on the question of a direct impact of MT on the

probability of crucial mistakes in ED, but merely gained more insight in the interdependence of MT with subjective parameters like stress level and SA that were known to correlate with the risk of errors from previous studies.

By evaluating the validity of our study, we need to question to which level of accuracy we were able to determine the Multitasking activity of ED providers within the chosen scientific model. First, when it comes to the role of the observer, the following potential shortcomings need to be discussed: Data were collected by different observers who might have interpreted given observation rules in lightly different ways. In order to assure reliability and conformity, each observer was doubled by a trained and experienced observer during the first training and observation session, and results were compared for agreement. No evidence was detected for critical deviations. Nevertheless, in a few critical situations with accelerating working mode and very fast switching tasks, the observer was unable to register all tasks one by one for practical reasons. This applied to consecutive tasks lasting less than about 30 seconds.

Second, the observed subjects did know the specific research questions, i.e., the association of multitasking behaviors and stress levels. Still, they were asked to “ignore” the presence of the observer. Also, they were instructed to perform their usual work as defined by the typically unforeseen medical cases in the ED and, above all, they were not given the opportunity to choose their favorite activities due to the fact of being observed. Though, it cannot be strictly excluded that in the sense of “seemingly desirable behavior” observed subjects tended to avoid MT combinations that might be related to safety risks. And they might have consciously chosen MT combinations they felt comfortable with. Yet, we did not detect any indication of such selective behavior.

Third, important data resulted from self-assessment as collected by the questionnaire: these parameters were not objective, but already well established by previous studies. Also, as given by design, a time delay was unavoidable between potentially critical MT activities and the moment of answering the questionnaire. This might have affected the results in a way difficult to reproduce and to trace back, e.g., through hindsight bias. The questions on self-perceived stress, in particular, asked for the rating of specific emotions that might have been subjectively considered “normal” in retrospect. Indeed, this might be a reason why we did not see statistical evidence of a correlation between MT and stress level.

For questions concerning SA, on the other hand, it is obvious that no technique can accurately redraw both *mental picture* and reality and compare the two objectively. So, the general approach to rely on subjective data seems to lack alternatives. Indeed, the time delay might have helped subjects to appropriately assess the levels of SA, as they had some time to actually watch the immediate effects of their efforts. Also, they made their assessment based on the knowledge of what had happened during the full period of observation. Although the design might have supported them to draw realistic conclusions, they were limited to their own *mental picture* and were possibly still missing an accurate picture of reality (Endsley 1999). Yet, we attribute satisfactory validity to the self-perceived SA. Variations from questionnaire to questionnaire seemed to be sufficiently significant so as to trust the SA values when compared relative to each other. Primarily, we draw confidence from the fact that the questionnaire has been evaluated within precedent studies.

Finally, we had to accept the following general limitations of data collection in ED:

Being a complex sociotechnical system, an ED cannot be properly described by 11 questions, an observation tool and several process parameters. Obviously, there are many more relevant factors for mental stress and SA in the ED as described above. Indeed, there have been attempts to simulate the processes in an emergency department and even an entire hospital (Günal and Pidd 2010), but it seems rather difficult to simulate a situation that reveals the stress level realistically. Generally, existing simulation models aimed to increase throughput (Konrad, DeSotto et al. 2013) out of economic interests.

The daily work of ED providers is relatively complex. Our approach was based on the assumption to picture a representative cross-sectional assessment within 90 minutes. As a full shift takes at least 8 hours, and ED providers also work at night, external validity of our data is confined. It is also worth mentioning that observations had to be paused once a patient would not give his consent. Notably, this occurred only in very few cases so that a potential statistical effect might be neglectable.

6. Implications for ED practice and future studies

Our study does not suggest any reason that MT should be avoided or could lead to unwanted effects in terms of provider cognition. In correlation to higher MT ratios, we found no increase in stress levels and, indeed, a positive effect on SA. On the other hand, the study did not put us in the position to clearly disprove the assumption that extended MT might be connected with crucial risks.

Within the design of our study, ED professionals proved sound ability to decide when to perform MT and when not. This conclusion was also supported by the finding that certain combinations of activities occurred frequently in MT whereas other combinations were recorded rarely. This result seems worthy to be further investigated in future studies, possibly by taking into account the cognitive-psychology-theory of multiple resources (Wickens 2008a): We suggest testing different task combinations in more detail while classifying tasks by the modalities they draw upon of.

As a matter of fact, the observed ED providers differed as to professional background, i.e., some had many years' experience in out-of-hospital emergency medicine, some others just had finished their formation. Our findings, therefore, represent the overall average for all levels of experience. Future investigations might include potential influences of provider's professional experience and tenure, skill level, and behavioral strategies to cope with exceeding workload, competing demands and multitasking situations.

Following previous contributions in literature, it is important to identify and train MT (Skaugset, Farrell et al. 2016). In the given context, this means first of all to train single tasks up to automation (e.g., technical skills in acute patient care). This suggests that besides teaching the theoretical knowledge of clinical picture, as well as diagnostic and therapeutic needs, also the basic procedures need to be trained in order to be able to perform multiple tasks simultaneously and, in addition, to improve SA. Again, in order to evaluate this hypothesis, future studies might investigate the coping strategies applied by ED providers when facing stressful situations as well as their cognitive sequelae, e.g. SA. And with additional attention to the influence of personal characteristics like a special focus on the level of professional experience.

7. Conclusions

By this work it was shown for the ED under investigation that MT was performed for a total time of about 6 minutes per hour on average. This compared to an average of about 40 activities per hour by each ED provider with about 5 activities involved in MT situations. Most commonly combined tasks were documentation and communication with patients or colleagues. The reported stress level was around a medium level at 2 out of 4 points. Nurses reported higher stress levels with increasing number of patients. ED physicians' stress levels did not correlate with any of the measured parameters. Physicians recorded higher SA with increasing MT ratio and also with increasing number of high-risk patients in the ED. Among the individual SA components, we identified a significant association for the question concerning predicting future developments.

This study underlines that ED providers cope within a substantial time of their clinical work with concurrent task demands. Our findings corroborate the importance of MT demands in emergency care and the needs to systematically address this issue in order to reduce the risks to patient and provider safety in the ED.

8. Appendix

Table 11. ***Influence of workload and Multitasking count ratio on the ED providers' stress assessment – by professions***

	ED profession					
	total		nurses		physicians	
Determinant	**β**	**p**	**β**	**p**	**β**	**p**
high-risk patient ratio	.214	.061	.254	.071	.228	.257
number of patients	.219	.056	**.328**	**.026**	.043	.831
number of colleagues	.02	.987	.261	.066	-.099	.614
MT count ratio	-.029	.797	-.043	.763	-.084	.669

Notes ED (emergency department), MT (Multitasking), β (standardized regression coefficient), p (p-value)

Table 12. ***Influence of workload and Multitasking count ratio on the ED providers' Situational Awareness – by professions***

	ED profession					
	total		nurses		physicians	
Determinant	**β**	**p**	**β**	**p**	**β**	**p**
high-risk patient ratio	.022	.856	-.26	.093	**.409**	**.024**
number of patients	-.167	.161	-.175	.245	-.124	.468
number of colleagues	.142	.244	-.197	.202	.292	.09
MT time ratio	.157	.204	-.091	.541	**.473**	**.009**

Notes ED (emergency department), MT (Multitasking), β (standardized regression coefficient), p (p-value)

Table 13. *Prevalence of observed tasks in ED: primary tasks in total and per ED profession*

	primary task (total)			primary task (nurses)			primary task (physicians)		
observed tasks	N	duration	time ratio	N	duration	time ratio	N	duration	time ratio
1 Patient/ Relatives communication	523	09:23:48	7.9%	283	04:15:08	5.8%	240	05:08:40	11.1%
2 Diagnostics	432	11:46:52	9.9%	259	06:51:39	9.4%	173	04:55:13	10.6%
3 Therapy	760	22:15:22	18.6%	671	19:56:44	27.3%	89	02:18:37	5.0%
4 Consultancy	54	01:03:18	0.9%	10	00:06:43	0.2%	44	00:56:35	2.0%
5 Documentation/ Charting	957	22:39:30	19.0%	480	08:45:38	12.0%	477	13:53:53	30.0%
6 Communication with ED-staff	904	20:17:00	17.0%	571	12:27:44	17.0%	333	07:49:15	16.9%
7 Communication with other staff/ Telephone conversations	441	07:52:39	6.6%	239	03:44:44	5.1%	202	04:07:54	8.9%
8 Organization/ Workflow	820	16:14:21	13.6%	609	12:49:56	17.5%	211	03:24:24	7.4%
9 Meetings (regular/ irregular)	14	01:34:31	1.3%	7	00:29:11	0.7%	7	01:05:20	2.4%
10 Teaching/ Instruction/ Supervision/ Research	44	01:06:22	0.9%	20	00:23:35	0.5%	24	00:42:47	1.5%
11 Personal activities/ Breaks	61	05:12:10	4.4%	48	03:15:00	4.4%	13	01:57:09	4.2%
No observation possible	3	00:05:36	0.1%	2	00:04:54	0.1%	1	00:00:42	0.0%
Total	5013	119:31:29	100.0%	3199	73:10:58	100.0%	1814	46:20:38	100.0%

Note ED (Emergency Department), N (number of observed tasks)

Table 14. *Prevalence of observed tasks in ED: primary tasks in total (being part of MT or single tasks stand-alone), single tasks (without primary tasks being part of MT), MT in total and divided into primary tasks and secondary tasks*

	primary tasks in total			single primary tasks = Total – MT primary tasks			Multitasking						Multitasking sum of primary and secondary tasks		
							primary tasks			secondary tasks					
observed tasks	N	duration	ratio	N	duration	ratio	N	duration	ratio	N	duration	ratio	N	duration	ratio
1 Patient/ Relatives communication	523	09:23:48	7.9%	447	07:24:24	6.91%	76	01:59:24	16.0%	153	03:19:44	26.8%	229	05:19:08	21.4%
2 Diagnostics	432	11:46:52	9.9%	324	09:38:44	9.00%	108	02:08:08	17.2%	17	00:26:41	3.6%	125	02:34:49	10.4%
3 Therapy	760	22:15:22	18.6%	605	19:23:04	18.10%	155	02:52:18	23.1%	25	00:39:08	5.3%	180	03:31:26	14.2%
4 Consultancy	54	01:03:18	0.9%	44	00:46:47	0.73%	10	00:16:31	2.2%	7	00:05:13	0.7%	17	00:21:44	1.5%
5 Documentation/ Charting	957	22:39:30	19.0%	824	20:19:11	18.97%	133	02:20:19	18.8%	142	03:12:55	25.9%	275	05:33:14	22.4%
6 Communication with ED-staff	904	20:17:00	17.0%	852	19:20:40	18.06%	52	00:56:20	7.6%	206	03:12:06	25.8%	258	04:08:26	16.7%
7 Communication with other staff/ Telephone conversations	441	07:52:39	6.6%	376	06:30:00	6.07%	65	01:22:39	11.1%	25	00:21:42	2.9%	90	01:44:21	7.0%
8 Organization/ Workflow	820	16:14:21	13.6%	795	15:49:14	14.77%	25	00:25:07	3.4%	24	00:21:08	2.8%	49	00:46:15	3.1%
9 Meetings (regular/ irregular)	14	01:34:31	1.3%	14	01:34:31	1.47%	0	00:00:00	0.0%	3	00:06:51	0.9%	3	00:06:51	0.5%
10 Teaching/ Instruction/ Supervision/ Research	44	01:06:22	0.9%	40	01:02:38	0.97%	4	00:03:44	0.5%	24	00:31:42	4.3%	28	00:35:26	2.4%
11 Personal activities/ Breaks	61	05:12:10	4.4%	61	05:12:10	4.86%	0	00:00:00	0.0%	2	00:07:20	1.0%	2	00:07:20	0.5%
No observation possible	3	00:05:36	0.1%	3	00:05:36	0.09%	0	00:00:00	0.0%	0	00:00:00	0.0%	0	00:00:00	0.0%
Total	5013	119:31:29	100.0%	4385	107:06:59	100.00%	628	12:24:30	100.0%	628	12:24:30	100.0%	1256	24:49:00	100.0%

Note MT (Multitasking), ED (Emergency Department), N (number of observed tasks)

Table 15. *Task combinations in MT*

		Total Ratio primary task (119.5 hours)	MT Ratio in combination with secondary task											
			Total Ratio primary task in MT (12.4 hours)	Patient/ Relatives communication	Diagnostics	Therapy	Consultancy	Documentation/ Charting	Communication with ED-staff	Communication with other staff/ Telephone conversations	Organization/ Workflow	Meetings (regular/ irregular)	Teaching/ Instruction/ Supervision/ Research	Personal activities/ Breaks
primary task	1 Patient/ Relatives communication	7.9%	16.0%		1.7%	4.2%	0.0%	9.1%	0.0%	0.0%	0.9%	0.0%	0.0%	0.0%
	2 Diagnostics	9.9%	17.2%	11.1%		0.0%	0.2%	0.1%	4.0%	0.4%	0.0%	0.0%	1.4%	0.0%
	3 Therapy	18.6%	23.1%	10.2%	0.0%		0.3%	0.6%	10.2%	0.6%	0.5%	0.0%	0.7%	0.0%
	4 Consultancy	0.9%	2.2%	0.0%	0.6%	0.0%		1.3%	0.0%	0.0%	0.2%	0.0%	0.0%	0.0%
	5 Documentation/ Charting	19.0%	18.8%	5.1%	0.0%	0.0%	0.2%		10.2%	1.0%	0.1%	0.0%	1.9%	0.4%
	6 Communication with ED-staff	17.0%	7.6%	0.0%	0.4%	0.2%	0.0%	6.3%		0.2%	0.5%	0.0%	0.0%	0.0%
	7 Communication with other staff/ Telephone conversations	6.6%	11.1%	0.1%	0.8%	0.6%	0.0%	8.0%	0.1%		0.6%	0.9%	0.0%	0.0%
	8 Organization/ Workflow	13.6%	3.4%	0.4%	0.0%	0.1%	0.0%	0.1%	1.4%	0.6%		0.0%	0.2%	0.6%
	9 Meetings (regular/ irregular)	1.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%		0.0%	0.0%
	10 Teaching/ Instruction/ Supervision/ Research	0.9%	0.5%	0.0%	0.0%	0.1%	0.0%	0.3%	0.0%	0.0%	0.1%	0.0%		0.0%
	11 Personal activities/ Breaks	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
	Total Ratio secondary task in MT	100.1%	100.0%	26.8%	3.6%	5.3%	0.7%	25.9%	25.8%	2.9%	2.8%	0.9%	4.3%	1.0%

Note MT (Multitasking), ED (Emergency Department)

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11. Eidesstattliche Versicherung

Augenstein, Tobias

Ich erkläre hiermit an Eides statt,

dass ich die vorliegende Dissertation mit dem Titel

The effects of Multitasking on Stress and Situational Awareness: A multi-source study in the Emergency Department

selbständig verfasst, mich außer der angegebenen keiner weiteren Hilfsmittel bedient und alle Erkenntnisse, die aus dem Schrifttum ganz oder annähernd übernommen sind, als solche kenntlich gemacht und nach ihrer Herkunft unter Bezeichnung der Fundstelle einzeln nachgewiesen habe.

Ich erkläre des Weiteren, dass die hier vorgelegte Dissertation nicht in gleicher oder in ähnlicher Form bei einer anderen Stelle zur Erlangung eines akademischen Grades eingereicht wurde.

München 18.12.2020	Tobias Augenstein
Ort, Datum	Tobias Augenstein