EDITOR'S CHOICE

The association of workflow interruptions and hospital doctors' workload: a prospective observational study

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ABSTRACT

Background: Subjective workload in healthcare employees is suspected to be important for the performance and safety of healthcare delivery. This study investigates associations between workflow interruptions and hospital doctors' capability to manage their perceived workload in a safe and efficient manner.

Aim: To examine the relationship of observed workflow interruptions with hospital doctors' perceived workload during day clinical shifts.

Methods: A prospective study of 43 full shift observations with 29 doctors working in internal medicine and surgical specialties. Workflow interruptions were assessed via observation using a previously validated observation instrument. Doctors assessed their workload twice throughout their day shift using three items of the validated NASA-Task Load Index (NASA-TLX; mental demands, effort, frustration).

Results: Hospital doctors were on average disrupted 3.66 times per hour. Most frequent were interruptions by nursing staff, telephone/beeper interruptions and by fellow doctors. Senior doctors reported higher workload than their junior colleagues. Overall workflow interruptions were significantly related to doctors' workload (β=0.22; p=0.03). Further analyses revealed that doctors' workload was associated particularly with interruptions by nursing personnel (β=0.23; p=0.03).

Conclusions: Frequent workflow interruptions may be linked with increased workload in doctors. Healthcare environments need to be better designed to reduce unnecessary interruptions and distractions so that hospital doctors can manage clinical work efficiently and safely.

INTRODUCTION

There has been substantial growth in recent years in the research on workflow interruptions in healthcare workers.[1–5] Early research investigated prevalence as well as potential reactions to workflow disruptions.[6–8] Subsequent contributions emphasised potential effects of interruptions, such as their role as stressors and their potential detrimental impact on safety and quality of healthcare delivery.[2 5 9 10] Highly interruptive hospital environments are conducive to manifold performance consequences: at the individual level, distractions may be responsible for goal obstruction and detrimental task execution, thus jeopardising clinical performance and eventually patient care.[4 11–13] At the team level, interruptions may be responsible for suboptimal staff communication, unfocused diagnostic procedures or deficient handovers.[12 14]

Workflow interruptions and subjective workload in hospital doctors

Subjective workload is defined as 'the cost incurred by a human operator to achieve a particular level of performance. (…) it emerges from the interaction between the requirements of a task, the circumstances under which it is performed, and the skills, and perceptions of the operator.'[15] Perceived workload is a critical variable intervening between work demands and performance.[15–17]

Workflow interruptions may add to perceptions of workload. Healthcare professionals often need to perform complex tasks that demand undivided attention. Due to an interruption, the focal task (eg, to prescribe medication) is suspended to perform an unplanned task (eg, responding to colleague's question), resulting in discontinuous task performance.[9 18 19] Thus, an interruption is an obstacle to effective completion of goal-directed behaviour, hinders work performance and drives attention resources to be allocated to a break-in event.[20 21]

Moreover, interruptions may be conducive to erroneous performance, that is, picking up the wrong syringe due to a beeper call. For nurses, interruptions are linked to medication errors during drug administration.[8 22]

Interruptions can greatly add to stressors that are inherent in medical care and thus significantly increase stress by increasing demand upon the individual doctor—a phenomenon that has been described as 'the distractions-stress ladder'.[10 23] Employees who face frequent disruptions perceive their work as less controllable and predictable.[20 24] Ultimately, interruptions may be associated with increased workload, fatigue, stress and frustration,[25] which in turn are detrimental to performance of healthcare workers,[23 26] and also negatively affect patient safety and outcomes.[16 26 27]

Although there have been studies on disruptions to work performance within healthcare, limitations remain in the evidence base, particularly related to the association between interruptions and perceived workload. First, there are only few studies examining workflow interruptions in relation with hospital doctors outside emergency departments and operating theatres. Second, many of the applied studies are purely descriptive—in other words, they characterise the nature of interruptions faced by healthcare workers, but they do not directly link these interruptions with outcomes like workload, performance of healthcare personnel or patient safety endpoints. Thus, studies using valid and reliable assessments within real healthcare environments enable more robust investigation of the association between interruptions and observable outcomes (as opposed to studies carried out within simulation settings). Third, just a minority of studies explicitly address subjective and cognitive implications of interruptions.[2 5] Capturing potential cognitive decrements due to frequent workflow disruptions is a first step in order to create an effective cognitive environment for healthcare workers.[2] Fourth, distractions are generally thought to have their main impact through their immediate effects (eg, prescribing incorrect medication or picking up the wrong syringe). However, cumulative effects and the potential for longer term deterioration of performance are rarely addressed.

The aims of this study were to address these shortcomings and to contribute to the growing interruptions evidence base. Specifically, drawing on a sample of German hospital doctors we sought to:

1. assess the observed frequency of workflow interruptions and the extent of self-reported workload during a day shift;
2. identify work- or person-related influences on interruptions and subjective workload;
3. investigate associations between observed workflow interruptions and self-reported workload.

METHOD

Study setting

In a 300-bed general community hospital in Germany, observations were conducted as part of an ongoing quality improvement project. This is the same hospital where we developed and validated an observation method to assess workflow interruptions in hospital doctors.[28] The present study was conducted 13 months later with a newly recruited sample. The ethics committee of the Faculty of Medicine, Munich University, gave ethical approval for this study. The participation was voluntary and consent was obtained at least 1 day before the scheduled observation.

Study sample

The study included surgeons and internists largely undergoing postgraduate specialty training in four hospital departments: general surgery, trauma surgery, cardiology, and gastroenterology. To ensure a sufficient level of proficiency, participants had to have worked at least four months on the site. Furthermore, clinicians had to be assigned throughout the entire shift to a specified clinical unit. The observation dates were selected randomly. The clinical units of interest were eight wards, one intensive care unit (ICU; here only internists work), as well as the only interdisciplinary accident and emergency ward (A&E). All wards were comparable in terms of work organisation, bed capacity and staffing levels.

There were 34 eligible doctors within the four study departments. Overall, 43 full shift observations were conducted, in which 29 hospital doctors participated: N=14 women, 48.3%. Fourteen doctors were observed twice. Average age was 34.0 years (SD=7.02, range 27−57) and doctors already worked about M=3.73 years within this hospital (SD=4.38). Four doctors (13.8%) had a specialty degree, the others (N=25, 86.2%) were still in their postgraduate training. The majority (N=23, 79.3%) were working on junior-entry-level positions similar to UK house officer or specialty trainee level. Five were working as specialists which included supervisor duties.

Design and observation procedure

A prospective design was applied, combining structured full-shift observations and self-report measures. Structured expert observations have been shown to be useful in healthcare,[29 30] with particular application to the detailed identification and assessment of workflow interruptions.[5 13 28 31 32] To enhance the internal and external validity, full shift observations serve as meaningful way to cover extended time periods.[28 33 34] Two observers were trained prior to the study and tested for inter-rater agreement (see section below). They shadowed the doctors throughout the day shift, coded workflow interruptions and were instructed not to distract doctors or co-working staff.[28]

Doctors' self-report on their workload was collected twice: (1) 'morning', the questionnaire was administered at half-time of the shift (usually before starting lunch break; or midway of the shift if the doctor omitted lunch break); (2) 'afternoon', at the end of the shift when doctors had finished and were about to leave the clinic. Each time they were asked to report on their workload in relation to their work over the previous part of the shift.[35] Each time the instruction was: 'Please rate your average workload during the recent part of the shift you just completed'.

Measures: observation of workflow interruptions and doctors' workload

Data were collected on (1) source of workflow interruption and (2) doctors' workload:

Workflow interruptions

A validated tool to observe doctors' workflow interruptions was employed.[28] Doctors' workflow interruptions are defined here as an intrusion of an unplanned and unscheduled task, causing a discontinuation of tasks, a noticeable break, or task switch behaviour. The observation tool distinguishes ten sources of workflow interruptions[28]: (1) interruption by colleague doctors; (2) by nursing staff; (3) by telephone/beeper; (4) by patients; (5) by patients' relatives; (6) by any other person or employees; (7) interruptions due to equipment or technical malfunctions (ie, equipment dysfunctions or technical malfunctions); (8) information impediments (ie, necessary work information unavailable); (9) waiting time; and (10) motor or physical impediments (eg, noise, confined space for moving, additional physical strengths in moving heavy patients). Impediments (8−10) are considered as a special subset of workflow interruptions that force doctors to stop the ongoing activity to turn their attention to a disruptive incident and thus aggravate or delay task performance.[21 36]

Doctors' subjective workload

To assess the effects of demands imposed by clinical task requirements, an abbreviated three-item scale of the validated NASA Task Load Index (TLX) was applied.[15] This was designed as a multidimensional rating technique for the subjective assessment of load relevant to a given task or task section. It is sensitive to distinguish between different requirements or task levels, and also indicates objective performance.[15 37] This widely used tool indicates subjective workload and has been shown applicable to doctors' work in healthcare environments.[35 37 38] Due to resource constraints for this study three items of the NASA-TLX were employed: mental demands ('How mentally demanding was the task?'); effort ('How hard did you have to work to accomplish your level of performance?'); and frustration ('How insecure, discouraged, irritated, stressed and annoyed were you?'). The items were selected based on expert recommendations as well as literature reviews.[15 16 35 37] The scale ranged from 0 ('very low') to 100 ('very high'). The three items were aggregated to indicate doctors' overall subjective workload. Scale's reliability in terms of internal consistency was good in the main study: Cronbach's α=0.77.

Additionally, work-related information was noted at the beginning of the observations: clinical unit (ward, ICU, A&E); specialty (surgery, internal medicine); time of the day (morning or afternoon; workload was assessed at both time points). Furthermore, personal data of the involved doctor was collected via self-report: sex (male or female); professional tenure (time since graduation); organisational tenure (time since entry into hospital); specialty degree obtained (completed postgraduate degree); and position (junior, entry level doctors without supervisory responsibilities, specialists with supervisory duties).

Observation instrument: pilot testing of reliability

Three pilot observations were conducted on the site prior to the main study to test the reliability of the observation instrument in terms of inter-observer agreement.[39] Three hospital doctors were observed by the two observers simultaneously (three observation periods; range 56−75 min, sum 190.0 min). Thirty-two workflow interruptions were identified (rater 1: N=17; rater 2: N=15). The resulting kappa-coefficient based on the number of interruptions was 0.68 (T=9.45; $p<0.01$). This indicates substantial inter-rater agreement and supports previous reliability tests.[28 39]

Analysis

Observational as well as self-report data were recorded on clipboard paper sheets, transferred via double data entry into a database, and checked for errors and implausible values. For descriptive statistics we first computed sum and mean values for the variables of the study. For inferential statistics analyses of variance (ANOVAs) were performed to explore group differences. To examine associations between workflow interruptions and doctors' workload ratings we applied hierarchical linear regression analyses. To take account of potential bias we included in the first step, control variables and in the second step, the frequency of workflow interruptions.[40] All analyses were performed using SPSS V.18.0.

RESULTS

Overall 43 full-shift observations were conducted, with an overall duration of 414 h, 56 min and 23 s (24896.4 min). The average shift duration was about 9 h, 38 min and 59 s; SD (hh:mm:ss)=01:01:06; range 08:01:27–12:08:11. During all shifts doctors completed twice a self-rating, resulting in 86 workload evaluations.

Frequency of observed workflow interruptions

Overall, 1521 workflow interruptions were identified. On average, 17.7 interruptions were coded per full shift observation (SD=5.2; range 15–60). This means that hospital doctors were on average disrupted 3.66 times per hour (SD=1.39; range 0.91–7.88). Doctors' average workload was 46.45 (SD=17.29; range 15.0–87.5; Scale range from 0=very low to 100=very high).

Table 1 presents how often each of the different interruptions was observed within an observed working hour on average. Of all observed interruptions, most were caused by colleagues (n=1183; 74.8%). The rest were attributed to interruptions by others (n=214; 14.1%) and to impediments/delays (n=169; 11.1%). Regarding the sources of workflow interruptions by colleagues, interruptions caused by nursing staff occurred most frequently (n=449; 29.5%), closely followed by telephone/beeper interruptions (n=440; 28.9%) and interruptions by fellow doctors (n=249; 16.4%).

Relationships of clinical and personal variables, workflow interruptions and workload

Next, we checked for potential work-related (clinical unit, specialty, time of the day) and personal variables (gender, specialty, degree) that are associated with the frequency of observed workflow interruptions and doctors' workload ratings. Table 2 summarises the findings.

To investigate potential associations of doctors' work-related and personal variables for the two main study's variables we checked for mean differences (table 2). Regarding the work-related variables, we found that doctors rated their workload during the mornings almost significantly lower than during their afternoon shift (ΔM=7.02; p=0.059). In addition, we also found two trends in the data (that approached significance): doctors working in the emergency and intensive care units tended to score their workload higher than their colleagues on wards (ΔM=7.41, p=0.08) and rate of workflow interruptions tended to be more frequent in the internal medicine specialty than in surgical specialties (ΔM=0.51; p=0.09).

Regarding person-related variables, we found a significant influence of doctors' position (table 2): Senior, specialist doctors rated their workload higher than their colleagues at more junior level (ΔM=8.88; p=0.05). Additionally, we tested if the doctors' age and organisational tenure (years of working in current hospital) were associated with both outcome variables. On average, the hospital doctors were 34.0 years old (SD=4.38 years; range 27–57 years) and were employed in the hospital for 3.73 years (SD=7.02 years; range 0.4–34 years). Doctors' age was associated neither with workflow interruptions (Spearman ρ=−0.06, NS) nor with their workload ratings (ρ=0.07; NS). Also, no significant associations were found between organisational tenure and observed interruptions (ρ=−0.05; NS) or doctors' workload (r=0.12; NS).

Associations between workflow interruptions and subjective workload

To examine the association between observed workflow interruptions and hospital doctors' subsequent workload rating we applied hierarchical linear regression. As

Table 1 Frequency of single and categorised workflow interruptions

Category	Single workflow interruption	Observed workflow interruptions n (%)		Interruptions per hour M (SD)	
Colleague interruptions	Doctors	1138 (74.8)	249 (16.4)	2.73 (1.21)	0.63 (0.56)
	Nursing staff		449 (29.5)		1.07 (0.72)
	Telephone/beeper		440 (28.9)		1.05 (0.61)
Interruption by others	Patients	214 (14.1)	75 (4.9)	0.52 (0.44)	0.18 (0.29)
	Patients' relatives		58 (3.8)		0.14 (0.23)
	Any other person		49 (3.2)		0.12 (0.18)
	Equipment/technical malfunctions		32 (2.1)		0.07 (0.15)
Impediments/delays	Information impediments	169 (11.1)	82 (5.4)	0.41 (0.39)	0.20 (0.28)
	Waiting time		71 (4.7)		0.17 (0.24)
	Motor impediments		16 (1.1)		0.04 (0.10)
Overall		1521	3.66 (1.39)		

Note: 86 half shift observations; overall observation time: 414 h, 56 min, 23 s; n, number of interruptions.

Table 2 Descriptive statistics and difference tests of variables assessed in the study

	N	Total duration of observation (min)	Observed workflow interruptions (sum)	Interruptions per hour M (SD)	Doctors' workload rating M (SD)
Work-related variables					
Clinical unit					
Ward	62	17855.1	1057	3.55 (1.33)	44.38 (16.61)
A&E and ICU	24	7041.3	464	3.95 (1.53)	51.79 (18.23)
Significance (F; p)				1.50; 0.23	3.26; 0.08
Specialty					
Surgery	44	12554.38	721	3.41 (1.39)	46.38 (15.27)
Internal medicine	42	12342.02	800	3.92 (1.35)	46.52 (19.38)
Significance (F; p)				3.03; 0.09	0.00; 0.97
Time					
Morning	43	12770.5	811	3.82 (1.26)	42.94 (16.13)
Afternoon	43	12125.9	710	3.50 (1.50)	49.96 (17.88)
Significance (F; p)				1.15; 0.29	3.66; 0.059
Personal variables					
Gender					
Male	42	12440.13	740	3.54 (1.30)	46.73 (15.75)
Female	44	12456.27	781	3.78 (1.47)	46.18 (18.83)
Significance (F; p)				0.66; 0.42	0.02; 0.89
Position					
Specialist	18	5373.27	328	3.60 (1.42)	53.45 (10.91)
Junior level	68	19523.13	1193	3.68 (1.39)	44.6 (18.24)
Significance (F; p)				0.05; 0.83	**3.86; 0.05**

Significance testing ANOVA.
$p \le 0.05$ in boldface.
M, mean; N, number of half-shift observations.

control variables, we used time of the observation as well as doctor's position, because both variables showed near-significant associations to the workload ratings (table 2). Table 3 presents the regression estimates of the second step of the hierarchical regression:

Time of the day showed a significant association, such that doctors rated their workload during the afternoon period of the observation higher than during their morning work hours (table 3; β=0.23; p=0.03). Doctors' position was also significantly related to the subsequent workload ratings: senior doctors reported higher workload than their junior colleagues (β=−0.22, p=0.04). The estimation of the prospective association of workflow interruptions to subjective workload showed a significant result: observed interruptions were significantly associated with doctors' workload over and above the contribution of other variables (β=0.22; p=0.03). The three variables accounted for 14% of the variance in workload ratings and the change of R^2 was in both steps significant. To further check the robustness of our results due to double observations in 14 doctors we included a dummy variable into the regression, that is, so that individual bias in workload ratings can be taken into account. This additional control variable did not reveal significant relationship (B=0.68; SE=3.81; β=0.02; NS) and did not change the pattern of results either.

Table 3 Regression results: associations of interruptions and workload

	Dependent variable: NASA workload			
	B (95% CI)	SE	β	R^2 (ΔR^2)
Control variables (step 1)				
Time	7.92 (0.84 to 15.00)	3.56	**0.23***	0.09 (**0.09***)
Position	−9.07 (−17.71 to −0.43)	4.34	**−0.22***	
Predictor variable (step 2)				
Workflow interruptions	2.78 (0.22 to 5.34)	1.29	**0.22***	0.14 (**0.05***)

Note: time (1 morning, 2 afternoon); position (1 specialist, 2 junior level). Regression values of last step displayed. Constant values omitted.
B, unstandardised regression coefficient; β, standardised regression coefficient; R^2, variance explained (in boldface if significance level *$p<0.05$).

Further analyses elicited the contribution of each of the ten observed workflow interruptions to the workload rating. Here, a similar regression procedure and the same control variables were applied as outlined above (cf, table 2). Only interruptions by nursing staff showed a significant association with doctors' workload ratings: On average, 1.07 (SD=0.72) hourly workflow interruptions due to nursing staff were observed in course of the observations. In the regression analysis, nurses' interruptions were significantly related with subsequent doctors' workload, with: β=0.23, B=5.59, CI (B) 95%=0.60 to 10.58, SE=2.51, p=0.03.

DISCUSSION

This study aimed to investigate expert-observed workflow interruptions and self-reported workload in German hospital doctors by applying a prospective design (aim 1). Overall, doctors were interrupted on average 3.66 times per hour. A closer look revealed that interruptions by colleagues were by far most frequent, which is in line with our previous findings.[28] In detail, as interruptions due to nurses' and telephone/beepers occurred most often, the study supports the relative contribution of different sources of interruptions revealed by previous research.[28 35 41] Interruptions attributed to doctors' colleagues indicate the high levels of intra- and interprofessional communication in the hospital.[2 5 42] Moreover, this might also be attributable to healthcare staff's preference for 'interruptive communication mechanisms'.[7] Doctors' average workload ratings were moderate but varied throughout our observations. In line with one study in an emergency department we reason that this might be attributable to the unpredictable and rapidly changing nature of clinical workflow in the hospital.[37]

Second, the study aimed to examine potential associations of work and person-related characteristics and frequency of workflow interruptions as well as self-reported workload (aim 2). The level of interruptions was comparable across units, specialties and time of the day. These results are in contrast to previous findings showing that emergency and immediate care environments are prone to more frequent interruptions.[9 33 35] Regarding the workload level, a significant link to doctors' positions could be observed, such that specialists reported higher workload than their junior colleagues. This is in contrast to one study's finding showing that senior doctors in the emergency department tend to exhibit lower subjective workload scores than junior level doctors.[35] A potential explanation might be that senior doctors in emergency care tend to take a more active clinical load than those working on wards. Furthermore, workload reports during the mornings were lower than the reports on afternoon periods to a near-significant extent. This might relate to higher fatigue as a consequence of persistent workload.[26]

Aim 3 was to explore whether workflow interruptions are related to doctors' perceptions of workload. Controlling for time of the day as well as doctors' position, a significant positive association of observed workflow interruptions and subsequent workload ratings was identified, that is, observed interruptions accounted for 5% of the variance in doctors' workload ratings. The overall volume of workflow interruptions showed strongest association to workload, supporting the notion that multilayered disruptions to clinical work are likely to have an effect significantly more pronounced than the effect of individual distracting events.[10]

The results emphasise that interruptions are positively related to doctors' reported workload imposed by additional events or requirements. Existing evidence suggests that increased workload may interfere and degrade vigilance or memory processes that are important in resumption of interrupted tasks.[2] A study of healthcare workers' shows that workload is related to patient and safety outcomes.[26] While causal inferences cannot be made on this basis of the present, observational study (ie, we cannot delineate whether increased workflow interruptions lead to increased workload, or staff with generally higher workload tend to get interrupted more often), based on evidence in other settings we argue that excessive workload that is due to inefficient and disruptive work practice needs to be constrained because it can lead to adverse outcomes.[4 16 22]

Limitations of the study

First, the study employs a prospective design. Although this is a robust way to address prospective associations of interruptions and outcomes, an ideal study design to infer causality is still a controlled intervention trial. Moreover, due to our design we cannot exclude that the direction of the relationship of workflow interruptions and subjective workload may also be reverse, such that the busier doctors are, that is, the more workload and tasks they face, the more likely it is that they are interrupted. Second, the results are based on a single sample of a community hospital in Germany. Although we checked for comparability, selection bias may have occurred (such that hospitals taking efforts in improving work organisation take part in research and improvement activities). There is a noticeable disproportion in the sampling of clinical areas under study which can affect the results, that is, specific interruptions may be more likely within certain clinical areas.[35] We did not check for complexity, type and length of clinical tasks and were not able to control for length sampling bias, such that length of clinical tasks may increase the chance of being interrupted.[13] Third, potential observer effects may have biased the prevalence of interruptions' frequencies, that is, such that observed doctors avoid particular tasks prone to interruptions or co-workers do not interrupt due to observer presence. Additionally, full shift observations stress attention resources of the observers such that observer's fatigue increases with extended observation periods.

Fourth, workflow interruptions can be essential for clinical care. Thus, a rather nuanced standpoint to carefully discuss the 'necessity' or 'legitimacy' of workflow interruptions is required. In this study, only clearly observable, pre-defined workflow disruptions were recorded. But, different interruptions may have different effects and safety implications.[5 18 41 43] In terms of the 'ambiguous nature' of interruptions, three aspects deserve more conceptual clarification: First, content of interruptions, meaning that interruptions may also provide valuable clinical or process-related information, for example, clarification, immediate emergency response, acute error capture or essential information on subsequent tasks.[5 33] Second, 'opportune moments' in terms of 'reflexivity or self-regulating nature' of co-workers interruptions; as example, colleagues might pick appropriate times to interrupt each other whereas 'random' interruptions occur accidentally or arbitrarily, such as beeper calls.[28 41] Here, also the time of interruption within the task execution as well as the temporal difference between the actual moment of the workflow interruption and the corresponding reaction can be relevant, that is, the resumption lag or in terms of costs to memorise action intentions.[2 18 44] Third, doctors' individual perception of interruptive events may differ substantially according to severity, temporal duration, or nature of the event.[1 31] Although we aimed to take individual bias into account, potential moderating variables in this relationship may be left out, for example, subjective appraisal of legitimacy of disruption event.

Finally, workload is assessed by self-report measures. Although the applied instrument is indicative of objective workload, external criteria for workload are needed to reduce subjective bias.[15] But, doctors' work is partly non-deterministic and rapidly changing and makes it therefore difficult to track with objective workload measures.[37] Although our reports on task-load were in range compared with similar studies in hospital doctors, comparability is limited because of studies' contextual and measurement characteristics, for example, different clinical areas, report of weighted TLX scores.[16 35 37] Additionally, we did not directly assess 'cognitive load' of observed doctors, that is, degree to which working memory capacity is demanded. This is known to be a mediator between our susceptibility to interruptions and its impact on memory, resumption lags and detrimental task execution.[2 45] Although subjective workload is a complex construct our task-load measure is also indicative of cognitive task demands.[15 17]

The results of the present study carry several implications. Clinically, addressing and reducing unnecessary workflow interruptions is a feasible option to improve doctors' well-being.[10 20] Compared with our previous work this study contributes novel information on influences of workflow interruptions' on doctors' subjective reactions, in terms of increased workload and enhanced psychophysical strain.[20 28] In order to reduce future mistimed workflow interruptions by nursing staff, enhanced inter-professional collaboration through better organisation of various tasks and deliberate design of joint activities, communication processes and information transfer is advised.[14 46] In addition, we suggest team-based interventions to identify, increase awareness of, and eventually reduce inappropriate situational interruptions in clinical departments. Reducing mutual workflow interruptions and structuring inter-professional collaboration can be a promising strategy to enhance performance, patient outcomes, as well as clinical safety.[46] Furthermore, research evaluating implementation of information technology and its potentially beneficial effect on streamlining inter-professional coordination and thereby reducing interruptive work patterns and workload might also be a fruitful avenue for the future.[35]

Regarding research implications, the study provides ground for further questions to be addressed. Further research should aim to investigate the causal direction of workflow interruptions and subjective workload; if doctors' high workload accumulates more workflow interruptions or if frequent disruptions cause increased workload? We found an association of cumulative interruption measures but only one effect with regard to single sources, that is, interruptions due to nurses. Further research may explore multilayered as well as differential effects between single sources of interruptions, concurrent activities, as well as individual consequences. Empirical evidence to link interruptions, increased workload, stress and subsequent performance in doctors is lacking. A first attempt, proposed as the 'the distractions-stress ladder', hypothesises stages in which interruptions add upon increased demands, demands subsequently outweigh resources and stress levels increase with detrimental impact on clinical performance.[10] Subsequent fatigue and failures at work might occur as direct costs of sustained efforts to show high job performance in an interruptive clinical environment.[47] Investigating the impact of interruptions on stress alongside individual doctors' compensatory strategies may be a promising avenue for future research, that is, identifying and training in effective coping strategies and how best to implement them at the clinical workplace.[48]

Conclusions

The study found a relationship of observed workflow interruptions and subjective workload in hospital doctors. Eventually, they may have a similar effect on efficiency of clinical work as well as patient safety. To reduce inappropriate workflow interruptions, healthcare environments need to be better designed, sociotechnical systems balancing human-human and human-technology interactions, that is, aligning human-oriented re-design-efforts with needs for effective and safe functioning of healthcare delivery.[5] It is important to note that interruptions may also be purposeful, ensuring a quick and successful function of healthcare delivery or providing timely critical information.[5 18] Therefore a two-folded strategy to design an 'interruption resilient work' of hospital doctors is recommended: On the one hand, maintain inevitable, necessary interruptions that support clinical workflow, collaboration and contribute to safety; on the other hand, remove or reduce unnecessary, ineffective interruptions that have detrimental outcomes.[5]

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