The science of interruption

Enrico Coiera

There has been a steady growth of research into interruption spanning two decades. The first observations indicating that interruptions appeared to be commonplace in busy clinical settings like the emergency department[1–5] were soon followed by a potential link between interruptions and clinical error.[6] We now know that the act of interruption is pervasive,[7–9] perhaps universal, in clinical practice (and indeed most of life). Even apparently quiet and controlled spaces like the operating theatre are home to frequent interruption.[10] [11] There are now also robust studies demonstrating the sometimes negative impact of interruption on clinical work,[12] and in the genesis of error.[13–15]

Interruption science is thus important in its own right. As importantly, it also provides us with a model for how we can approach the broader study of socio-technical systems in patient safety. The realisations that clinical work is complex, and that safety is an emergent property of local context, are all mirrored in the study of interruption. There is thus much to be learnt from the specific analysis of interruptions for the broader study of clinical work and patient safety.

Studying interruptions is, however, challenging.[16] [17] It is still hard to predict the impact of interventions designed to minimise the effects of interruptions, or even to understand when such interventions are needed. Untangling this nuanced story could take a while, were it not for the work of researchers from other

Correspondence to Professor Enrico Coiera, Centre for Health Informatics, Australian Institute of Health Innovation, University of New South Wales, Sydney, NSW 2055, Australia; e.coiera@unsw.edu.au

disciplines. Psychology, in particular, has a large corpus of research, often from controlled laboratory studies, that tease apart the mechanics of how interruption disrupts cognition.[18] [19] The field of human computer interaction (HCI) explores how interruption disrupts the way we interact with technology, how technology design can be interruptive (think pager or mobile phone) and, crucially, how technology can be designed to make its users tolerant to interruption.[20] [21]

For interruption science in healthcare to mature further, and make a significant impact on our understanding of health systems, and indeed improve those systems, a number of challenges now need to be met by the research community.

THE CHALLENGE OF METHOD

Looking back over the current state of interruption research in healthcare, the majority of papers have focused on simple counting studies using a variety of methodologies to demonstrate the extent and distribution of interruption across a variety of clinical settings and professional groups. Comparison across these studies is often difficult for a number of reasons.

First, and worryingly, the definition of what an interruption actually is varies across studies.[15 22 23] Studies of computer alerts sometimes confuse the matter further by using the term 'interruptive alerts' when they actually mean 'modal' interaction, as defined in the HCI literature. There needs to be a standardised way of defining and counting interruptions, and the methods from psychology are probably the gold standard that we should use.

Second, the instruments used to count interruptions are not standardised, partly because of definitional variation, and partly because there are competing observational tools. It would be useful for the interruption research community to first review, and then come together to standardise working definitions and instruments. It should no longer be acceptable for researchers to invent new instruments without benchmarking their performance against existing ones.

The recent tradition in health research is to study interruptions in the real world using observational methods, which is a departure from the controlled and experimental approaches in both HCI and psychology. This has meant, primarily, that we genuinely have had to innovate in the development of observational instruments, but it also limits the generalisability of our findings and our ability to assign causality to what we see.

For example, first principles suggest that interrupted tasks should take longer to complete. However, the association between an interruption and longer task time has two causal readings. While an interruption to a task may make a task longer, it is also the case that the longer a task, the probability that it will be interrupted is also higher (called length-sampling bias). In a recent emergency department study, while the raw data showed that interrupted tasks were indeed longer, once length-sampling bias was accounted for, the surprising result was that interrupted tasks were shorter, not longer.[12]

There are several lessons here. First, one should always be careful to attribute causality when association is demonstrated in observational studies. In this issue, Weigl *et al* report an association between interruption rate and subjective assessment of workload.[24] However, as they acknowledge, whether more

interruptions lead to a higher perceived workload or whether those with high workloads attract more interruptions is unclear—the causality can and probably does go both ways. Second, it is clear that the effects of interruption are context specific. In busy settings, it seems that interruptions 'steal' from a fixed time budget of the primary task, and the only recourse is to hurry up or cut corners so that the next task can be started. In different settings, the literature tells us that when there is no time budget, we do see interruptions resulting in the lengthening of tasks.[25]

While there is much to be learnt from observational studies 'in the wild', controlled laboratory studies allow precise testing of causal propositions. While such experiments are the norm in HCI and psychology, they are rarely used in healthcare,[26] and should be used more often. The only way to settle whether interruptions increase a clinician's mental workload, memory load or task completion time in clinical task settings is to experimentally control the setting and use a randomised experimental design. Given the challenges of studying clinical settings, there is also a place for simulation studies that permit analysis of long-run behaviours, and reveal patterns that cannot be seen through labour-intensive observation or experimentation.[16 27]

THE CHALLENGE OF THEORY

Our understanding of the genesis of interruption, and its impact on human cognition, is becoming more fine grained. Not all interruptions are harmful, and there are settings in which interruptions appear well tolerated.[26] As many are swift to point out, interruptions are often useful and effective tools for getting clinical work done, for managing urgency and for opportunistic completion of tasks when appropriate individuals appear.[17]

Indeed, interruptions are a complex phenomenon where multiple variables including the characteristics of primary tasks, the cognitive state of the individual being interrupted, the interruptions themselves and the environment within which interruptions occur, all may influence patient safety and workflow outcomes.[16] This explains, in part, why it has been a challenge to synthesise or even interpret past research on the clinical impact of interruptions, because of the absence of common theoretical models, and heterogeneity in clinical settings, tasks, definitions and methods used.[23] Many studies have been small and underpowered, and it is only now becoming clear that the context in which an interruption occurs is a significant determinant of whether or not it will have an impact,[16] making generalisation from individual studies difficult. Context is everything, and clear descriptions of primary tasks, task sequences, interruption type and position in a task sequence, and memory prompts are essential to fully understand the results of individual studies.

We thus need to move from counting interruptions to understanding them. This means that we need stronger theoretical underpinnings to our research. Psychological research is paramount here, given its rich theoretical contributions to interruption science.[6 23] Understanding that the impact of an interruption is dependent on its position in a sequence of tasks,[28] how the interruption is handled or by the existence of memory cues in the working environment to assist task resumption after interruption, all help us explain the complex phenomena we observe in clinical settings.[19]

THE CHALLENGE OF TRANSLATION

The time has surely come when every interruption study includes clinical

outcome variables, whether they be impact on the efficiency or safety of clinical processes, or hard outcomes like morbidity and mortality. Few current studies explore the impact of interruptions on any outcome variables, which context variables are associated with negative outcomes or how outcomes can be improved through reduction of interruptions.[15] Simply counting more interruptions is unlikely to be helpful. We should, instead, be moving strongly from simply observing the effects of interruptions to studying how one can mitigate their adverse effects, and design clinical workflows and systems that either minimise or are tolerant to interruption effects.

The translation of interruption research has two broad goals. First, we need to understand which clinical tasks or which clinical settings are most at risk of the negative impacts of interruption. Second, we need to explore a variety of approaches to make these targets 'interruption-proof'.

There are several places in clinical practice where interruptions appear a risky proposition. Medication administration,[14] the preparation of chemotherapy,[29] injectables[30] and intravenous fluids[31] have all been identified as frequently interrupted activities with a risk of patient harm. More generally, cognitive psychology suggests that there is risk in any setting where a task occupies significant attentional and memory resources for an individual, where there may be a sequence of subtasks, where the interruption is similar to the primary task and where there are few external aids to assist resumption from interruption.[19] This list suggests that many clinical procedures, from induction of anaesthesia to insertion of central lines, may be opportunities for harm with interruption, and more effort is needed to understand the precise set of situational attributes that make a setting at risk from interruptions.

Mitigating the opportunity for harm raised by interruption can be approached with a variety of methods. First, we can intervene to reduce the number of interruptions in a given setting. Working out the reasons why people interrupt each other, and finding alternate ways of supporting these information needs is an obvious strategy. If staff ask each other for routine information such as phone numbers, equipment location or how to use 'the computer', then better support of these informal information needs should translate into lower interruption rates.[1] Educating clinical staff about the impact of interruption on patient safety should probably now be routine so that unnecessary or non-urgent communications are avoided or delayed. Any such educational programme should always carry the caveat that where there is concern for the safety or care of individuals, that interruption is always appropriate. Formal rules for interruption might be developed, but clinical decisions always require human judgement, and if a junior staff member is worried, they should be free to interrupt in a non-judgemental atmosphere.

Another approach to reducing interruption is to provide environmental cues to clinical staff either that they are entering a zone of higher risk, or that particular individuals are currently engaged in a risky task, and that interruption is not permitted or is limited to urgent communication. The idea of creating such 'no interruption zones' (NIZs) borrows much from the idea of a sterile cockpit in aviation.[32] Some studies are now actively testing the merit of NIZs, with promising results, both in reduction of raw interruption numbers and improvements in outcome measures.[33 34]

If interruptions cannot be avoided, then a further set of interventions exist to assist individuals in managing the negative impacts of interruption.

Clinicians can be taught a number of interruption-handling strategies and trained in multitasking, stretching from how they choose to respond to a request for interruption (saying 'no' is always an option), how to suspend a primary task in a state that makes it easy to return to and how to resume a previously interrupted task.[16 19 35]

Clinical environments and computer technologies can also be better designed to deal with interruption. For example, it appears that an individual's capacity to recover from interruption is aided by environmental memory cues.[25] When calculating a drug dose on paper, after an interruption the paper acts as a cue to help a clinician re-engage with the task, thus minimising error. Harnessing this understanding of interruption should help in the design of systems, such as electronic prescribing technologies,[26] that are tolerant of their users being interrupted. Designing interfaces that make it clear what the current task is, where the user is up to in that task, and intermediate calculations, decisions or data used in the task, should all help make computer systems better suited to busy and interruptive clinical environments.

In summary, interruption science is of increasing importance in the endeavour to make healthcare safer and more effective, as the impact of interruptions become ever more apparent. The complex socio-technical nature of interruption, however, will not yield to the standard linear analyses so much loved in healthcare. This makes the study of interruption an important model for health services researchers more broadly. As we unravel the complex nexus between the design of clinical work, our workspaces and human cognition, we will not just understand interruption, we will understand much about clinical safety.

Competing interests None.

REFERENCES

1. Coiera E. Clinical communication: a new informatics paradigm. *Proc AMIA Annu Fall Symp* 1996:17—21.
2. Coiera E, Tombs V. Communication behaviours in a hospital setting: an observational study. *BMJ* 1998;316:673—7.
3. Chisholm C, Collison K, Nelson D, et al. Emergency department workplace interruptions: are emergency physicians "interrupt-driven" and "multitasking"? *Acad Emerg Med* 2000;7:1239—43.
4. Chisholm CD, Dornfeld AM, Nelson DR, et al. Work interrupted: a comparison of workplace interruptions in emergency departments and primary care offices. *Ann Emerg Med* 2001;38:146—51.
5. Coiera E, Jayasuriya R, Hardy J, et al. Communication loads on clinicians in the emergency department. *Med J Aust* 2002;176:415—18.
6. Parker J, Coiera E. Improving clinical communication: a view from psychology. *J Am Med Inform Assoc* 2000;7:453—61.
7. Westbrook JI, Ampt A, Kearney L. All in a day's work: an observational work measurement study to quantify how and with whom doctors on hospital wards spend their time. *Med J Aust* 2008;188:506—9.
8. Westbrook JI, Duffield C, Li L, et al. How much time do nurses have for patients? A longitudinal study of hospital nurses' patterns of task time distribution and interactions with other health professionals. *BMC Health Serv Res* 2011;11:319.
9. Alvarez G, Coiera E. Interruptive communication patterns in the intensive care unit ward round. *Int J Med Inform* 2005;74:791—6.
10. Healey AN, Sevdalis N, Vincent CA. Measuring intra-operative interference from distraction and interruption observed in the operating theatre. *Ergonomics* 2006;49:589—604.
11. Savoldelli GL, Thieblemont J, Clergue F, et al. Incidence and impact of distracting events during induction of general anaesthesia for urgent surgical cases. *Eur J Anaesthesiol* 2010;27:683—9.
12. Westbrook JI, Coiera E, Dunsmuir WT, et al. The impact of interruptions on clinical task completion. *Qual Saf Health Care* 2010;19:284—9.
13. Flynn EA, Barker KN, Gibson JT, et al. Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *Am J Health Syst Pharm* 1999;56:1319—25.
14. Westbrook JI, Woods A, Rob MI, et al. Association of interruptions with an increased risk and severity of medication administration errors. *Arch Intern Med* 2010;170:683—90.
15. Biron AD, Loiselle CG, Lavoie-Tremblay M. Work interruptions and their contribution to medication administration errors: an evidence review. *Worldviews Evid Based Nurs* 2009;6:70—86.
16. Magrabi F, Li S, Dunn AG, et al. Challenges in measuring the impact of interruption on

patient safety and workflow outcomes. *Methods Inf Med* 2011;50:447—53.

17. Rivera-Rodriguez AJ, Karsh BT. Interruptions and distractions in healthcare: review and reappraisal. *Qual Saf Health Care* 2010;19:304—12.

18. Trafton JG, Monk CA. Task interruptions. *Rev Hum Factors Ergon* 2007;3:111—26.

19. Li SY, Magrabi F, Coiera E. A systematic review of the psychological literature on interruption and its patient safety implications. *J Am Med Inform Assoc* 2012;19:6—12.

20. McFarlane DC, Latorella KA. The scope and importance of human interruption in human-computer interaction design. *Hum Comput Interact* 2002;17:1—61.

21. Andrews A, Ratwani R, Trafton G. Recovering from interruptions: does alert type matter? *Proc Hum Factors Ergon Soc Annu Meet* 2009;53:409—13.

22. Brixey JJ, Robinson DJ, Johnson CW, et al. A concept analysis of the phenomenon interruption. *Adv Nurs Sci* 2007;30:E26—42.

23. Grundgeiger T, Sanderson P. Interruptions in healthcare: theoretical views. *Int J Med Inform* 2009;78:293—307.

24. Weigl M, Müller A, Vincent C, et al. The association of workflow interruptions and hospital doctors' workload: a prospective observational study. *BMJ Qual Saf* 2012;21:399—407.

25. Altmann EM, Trafton JG. Task interruption: resumption lag and the role of cues. *Proceedings of the 26th annual conference of the Cognitive Science Society (Chicago, IL, August 5-7, 2004)*. CogSci 2004. Hillsdale, MI: Lawrence Earlbaum associates, Inc., 2004:42—7.

26. Magrabi F, Li SY, Day RO, et al. Errors and electronic prescribing: a controlled laboratory study to examine task complexity and interruption effects. *J Am Med Inform Assoc* 2010;17:575—83.

27. Dunn A, Ong M, Westbrook J, et al. A simulation framework for mapping risks in clinical processes: the case of in-patient transfers. *JAMIA* 2011;18:259—66.

28. Li SY, Blandford A, Cairns P, et al. The effect of interruptions on postcompletion and other procedural errors: an account based on the activation-based goal memory model. *J Exp Psychol Appl* 2008;14:314—28.

29. Trbovich P, Prakash V, Stewart J, et al. Interruptions during the delivery of high-risk medications. *J Nurs Adm* 2010;40:211—18.

30. Bateman R, Donyai P. Errors associated with the preparation of aseptic products in UK hospital pharmacies: lessons from the national aseptic error reporting scheme. *Qual Saf Health Care* 2010;19:1—6.

31. Moss J, Berner E, Bothe O, et al. Intravenous medication administration in intensive care: opportunities for technological solutions. *AMIA Annu Symp Proc* 2008:495—9.

32. Hohenhaus SM, Powell SM. Distractions and interruptions: development of a healthcare sterile cockpit. *Newborn Infant Nurs Rev* 2008;8:108—10.

33. Anthony K, Wiencek C, Bauer C, et al. No interruptions please: impact of a no interruption zone on medication safety in intensive care units. *Crit Care Nurse* 2010;30:21—9.

34. Scott JJ, Williams DD, Ingram JJ, et al. The effectiveness of drug round tabards in reducing incidence of medication errors. *Nurs Times* 2010;106:13—15.

35. Boehm-Davis DA, Remington R. Reducing the disruptive effects of interruption: a cognitive framework for analysing the costs and benefits of intervention strategies. *Accid Anal Prev* 2009;41:1124—9.