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Effects of Interruptions on Doctors' Diagnostic Reasoning and Diagnostic Performance: An Experimental Study with Internal Medicine Residents

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Abstract

Introduction: Attention to medical errors, adverse events, and the resultant literature has grown exponentially over the last decade. Diagnostic errors can occur across various care settings and are multifactorial, encompassing system-related, cognitive, and patient-related errors. Among these factors, interruptions inevitably influence people's decision-making, performance, and behavior. Interruption during a cognitive task can affect the quality of decision-making in knowledge-intensive work environments. This study investigated whether interruptions during the diagnosis of cases can affect doctors' diagnostic performance.

Method: This is an experimental study in which doctors diagnose complex and simple cases with or without interruption during the diagnostic process. Participants were 40 third-year internal medicine residents in internal medicine from 3 teaching hospitals in Khartoum, Sudan. The participants diagnosed 8 clinical cases (4 simple cases and 4 complex cases) presented to them on a laptop computer. In half of the cases (2 simple cases and 2 complex cases), participants were interrupted by another task while diagnosing the case.

The primary outcome was a diagnostic accuracy score for simple and complex cases diagnosed with and without interruption. Time spent diagnosing the cases was also measured.

Results: Mean diagnostic accuracy (range: 0–1) was lower when participants were interrupted during diagnosis, both for simple (0.96, 95% confidence interval 0.92 to 1.00, without interruption; 0.74, 95% confidence interval 0.65 to 0.84, with interruption; $p < .01$) and for complex cases (0.78, 95% confidence interval 0.67 to 0.89, without interruption vs 0.58, 95% confidence interval 0.51 to 0.65 with interruption; $p = .01$). Interruptions caused doctors to spend less time while diagnosing both in simple (62.25 seconds, 95% confidence interval 52.8 to 71.68, without interruption vs 47.92 seconds, 95% confidence interval 42.55 to 53.30, with interruption; $p < .01$) and in complex cases (89.03 seconds, 95% confidence interval 74.17 to 103.87 seconds, without interruption vs 53.64 seconds, 95% confidence interval 46.02 to 61.26 seconds, with interruption; $p < .01$).

Conclusions: The study provided experimental evidence that interruptions during the diagnostic process cause doctors to speed up diagnostic decisions, causing diagnostic errors. Interruptions affect the diagnosis of both simple and complex clinical cases and may therefore threaten patient safety.

Introduction

Interruption is commonly defined as an interference that disrupts another person's talk, puzzles topic development, and causes premature decisions. [1] Doctors are often interrupted while seeing a patient, for example, by phone calls or consultations with colleagues. It is intuitively right to assume that these interruptions may affect physicians' reasoning and cause mistakes. Interruptions tend to be correlated with clinical errors and procedural failures. [2] Research in psychology suggests that interruptions certainly disrupt human cognition.[3, 4] It is not known, however, whether interruptions cause diagnostic

errors. This article reports on an experimental study with internal medicine residents investigating the effects of interruptions on doctors' reasoning and diagnostic performance.

Research on interruptions in clinical practice has grown in recent years, triggered by evidence of the deleterious consequences of interruptions in other domains, such as aviation. [5] Reducing interruptions has been proposed as an important intervention to minimize medical errors, but it is recognized that evidence of an association between interruptions and errors in other areas besides medication dispensing is insufficient.[5, 6] It seems clear that interruptions are very frequent and can occur in a broad range of settings and tasks related to patient care.[7] Interruptive, irrelevant communications, for example, have been found to occur at rates of 11.15 per hour in an emergency department. [8] And of 3.48 per surgical procedure.[9] When other types of interruptions, in addition to communicative interruptions, are considered, the frequency with which doctors are interrupted increases.[5] Most interruptions have the form of a "break-in-task," i.e., an event that not only diverts the physician's attention but results in switching to a new task with the assumption that the initial task will be resumed. [7]

It is, however, not clear whether these interruptions lead to diagnostic mistakes. Studies so far have had a descriptive or observational nature and have focused on the adverse effects of interruptions on the performance of surgical teams. [9–11] or therapeutic [12, 13] Procedures. Experimental evidence of the effects of interruptions on diagnostic reasoning is, to our knowledge, absent. Psychology research has shown that interruptions disrupt cognitive processes and indeed can induce errors. The limited capacity of our mental resources restricts the possibility of accurately performing two tasks simultaneously. [14, 15] Interruption and switching to another task may affect performance by interfering with the memory of information encountered in the original task, information that is essential to resume the original task effectively. [16] However, the time needed to re-involve with an externally interrupted task or self-interruptions may lead to a longer task completion time. [17] Limited processing capacity and forgetting can affect reasoning in other domains that are likely to disrupt doctors, but whether and how this occurs is unknown.

The study presented here investigated the effect of being interrupted while diagnosing a clinical case on physicians' mode of reasoning and diagnostic performance. We hypothesized that interruptions would speed up the diagnostic process relative to non-interrupted physicians, increasing the number of errors and reducing diagnostic accuracy. The negative effect of interruptions may be stronger in complex cases. Complex cases tend to be diagnosed more reflectively, with a more thorough analysis of clinical findings. We hypothesized that reflective reasoning processes may be more vulnerable to interruption than pattern recognition, a mode of reasoning often associated with simple cases.

Methods

Participants and Setting

Participants were 40 third-year internal medicine residents from 3 teaching hospitals in Khartoum, Sudan. All participants were in the same year of training for similar levels of expertise. The participants were randomly assigned to one of four versions of the program used for the experiment (see Materials and Procedures). Quiet settings (classrooms and meeting rooms) were assigned in the hospitals to ensure the privacy and accuracy of the experiment. All participants who volunteered for the study completed the assignment and received a small token equivalent to the fees for 1 working hour in the local context as compensation for their participation.

Material and procedures

The study used 8 written clinical cases selected from a set of cases used in previous studies with internal medicine residents. (15, 16) (See Appendix 1 for the list of cases.) The cases were selected based on the mean diagnostic scores obtained by the residents in those studies. So that set of 8 cases (4 simple and 4 complex cases) was included. Each case had a brief description of a patient's medical history, signs, symptoms, and test results. Appendix "2" presents an example of a case used in the study. All cases were based on real patients with a confirmed diagnosis. Two Sudanese consultants reviewed the cases to ensure their appropriateness for the local context.

Participants were asked to diagnose 8 cases and informed that, in some cases, they would be requested to work on another task while solving the case. The cases were presented to the participants on a laptop computer using E-prime 2.0 (Psychology Software Tools Inc., Pittsburgh, PA, USA). They were requested to read the case and subsequently sort the most likely diagnosis. Each participant diagnosed 4 cases (2 simple cases and 2 complex cases) without interruption, and 4 cases (2 simple cases and 2 complex cases) with interruption. The interruption consisted of a screen with a simple mathematical calculation to be solved, a calculation which was presented to the participant 20 seconds and 40 seconds after he or she started reading the clinical case. After each mathematical calculation, the screen with the case was shown again, and the participant continued working on the diagnosis until a decision was taken. To control order effects, 4 different versions of the program were prepared so that the sequence of presentation of the cases was counterbalanced. The same was done with the sequence of the conditions under which the cases would be solved (i.e., half participants started diagnosing cases without interruption, and the other half started with interruption). Participants were randomly assigned to work with one of the versions of the program. There were no time restrictions for decision-making. The computer software automatically registered the time spent diagnosing each case, as well as the participants' diagnoses.

Statistical analysis

Two experts in internal medicine independently evaluated the diagnoses made by the participants, without being aware of the conditions under which the case had been solved. A diagnosis was considered correct whenever the core diagnosis (e.g., "pneumonia" in the case of community-acquired pneumonia) was mentioned. When the participant did not cite the core diagnosis, but mentioned a

component of the diagnosis (e.g., “respiratory infection” in the same case), the diagnosis was evaluated as partially correct. Diagnoses that did not fall into one of the previous categories were considered incorrect. Diagnostic accuracy was rated as 1, 0.5, and 0 for completely correct, partially correct, and incorrect diagnoses, respectively. Raters agreed with 84% of their judgments, and differences were solved by discussion.

For each participant, the time spent diagnosing the 2 simple cases with and without interruption was separately summed, and the same computation was performed for the complex cases. Again, for each participant, we summed the diagnostic accuracy scores obtained in simple and complex cases diagnosed with and without interruption. We performed an analysis of variance (ANOVA) on the mean time spent in diagnosing, with “case complexity” (simple vs complex) and “interruption during diagnosis” (with vs without) as within-subjects factors. The hypothesis that interruption would hinder reflection and reduce time spent on diagnosing the cases was analyzed and tested. A second ANOVA with the same within-subjects factors was performed on mean diagnostic accuracy scores to test the hypothesis that interruption would decrease diagnostic performance, especially in complex cases. Paired t-tests (two-tailed) were used to compare the time spent diagnosing simple cases solved with and without interruption, and complex cases diagnosed with and without interruption. A second set of paired t-tests was performed to make similar comparisons for the diagnostic accuracy scores.

Results

Diagnostic accuracy

Table 1
Mean diagnostic accuracy scores as a function of case complexity and interruption during the diagnostic process

	Without interruption	**With interruption**	***P* value**
	Mean (95% CI)	**Mean (95% CI)**	
Simple cases	0.96 (0.92–1.00)	0.74 (0.65–0.84)	< .01
Complex cases	0.78 (0.67–0.89)	0.58 (0.51–0.65)	.01

The mean diagnostic accuracy scores for case diagnosis as a function of case complexity and interruption status are shown in Table 1. The analysis of variance showed a significant main effect of case complexity, F (1,39) = 22.80, p < .001, partial η^2 = .37, with physicians performing better in simple than in complex cases, both when they were and were not interrupted. This finding validates our distinction between simple and complex cases. A significant main effect of interruption was also found, F (1,39) = 23.69, p < .001, partial η^2 = .38. The two-way interaction was not significant, F (1,39) = .04, p = .85. Diagnostic accuracy was lower when **participants diagnosed simple cases** with interruption than when they were not interrupted, t (39) = 4.38, p < .001. Similarly, lower diagnostic accuracy was found

when **participants diagnosed complex cases** with interruption than when they were not interrupted $t(39) = 2.6$, $p = .01$. This indicates that interruption during the diagnostic process negatively affects the accuracy of the final diagnosis regardless of the complexity of the cases.

Time spent on diagnosis

Table 2
Mean time (in seconds) spent in diagnosis as a function of case complexity and occurrence of interruption during the diagnostic process

	With interruption	**Without interruption**	***P* value**
	Mean (95% CI)	**Mean (95% CI)**	
Simple cases	62.25 (52.81–71.68)	47.92 (42.55–53.30)	< .01
Complex cases	89.03 (74.17–103.87)	53.64 (46.02–61.26)	< .01

Table 2 shows the mean time spent diagnosing simple and complex cases when physicians were interrupted by another task during the diagnostic process and when they were not. The ANOVA showed a significant main effect of case complexity, $F(1,39) = 21.81$, $p < .001$, partial $\eta^2 = .36$, and a significant main effect of interruption, $F(1,39) = 30.50$, $p < .001$, partial $\eta^2 = .44$. The two-way interaction was also significant $F(1,39) = 7.85$, $p = .01$, partial $\eta^2 = .17$, which shows that interruption differentially affected time spent diagnosing cases of different levels of complexity. Interruption decreased time spent in diagnosing simple cases, $t(39) = 3.25$, $p = .002$, as well as complex cases, $t(39) = 5.03$, $p < .001$, indicating that physicians tend to reflect less on the case and speed up decisions when they are interrupted during the diagnostic process. However, participants were faster in diagnosing simple cases than complex cases when they were not interrupted, $t(39) = 4.53$, $p < .001$, but this difference between time spent to diagnose cases of distinct levels of complexity was not found when interruptions occurred during the diagnosis, $t(39) = 1.36$, $p = .18$., which suggests that the speeding-up effect of interruption is stronger in complex cases.

Discussion

Our findings support the hypothesis that physicians accelerate decisions when interrupted during the diagnostic process: they spend less time diagnosing both simple and complex cases, although this effect is stronger in complex cases. The effect of interruption on diagnostic accuracy appeared to be more pervasive than we expected: diagnostic accuracy was lower when physicians were interrupted during the diagnostic process, not only in complex but also in simple cases.

These findings may be explained by difficulties in dealing with interruptions from the limited capacity of working memory. If someone is interrupted, attention is redirected to the new task and, when the interrupting task has been completed, resumption of the original task will occur. [16] This requires memory for important information (e.g., where one has stopped, what is still left to be checked, and what

is to be done next) from the original task. Information acquired later, in the second task, may interfere with the ability to retain information that came earlier, in the original task, leading to failure in resuming it correctly, which tends to increase the chance of errors. [2, 16, 18] In our experiment, participants were interrupted twice. Doctors are known to generate diagnostic hypotheses early in a clinical encounter through pattern recognition, a fast, largely unconscious process based on the recognition of similarities between the actual case and examples of patients seen before or prototypical scripts of diseases stored in memory. [19, 20] Therefore, in some cases, doctors may have already generated a first diagnostic hypothesis when they were interrupted. If findings from research in other domains [16, 18] apply to medicine, they probably face difficulties returning to the case after the interruptions. They may have, for example, forgotten where they had stopped or may have overlooked a finding contradictory to their initial hypothesis. These difficulties in resuming case processing were overwhelming enough to lead the doctors to speed up the diagnostic process, as suggested by the decrease in the time spent on diagnosing when participants were interrupted compared to cases solved without interruption. Such difficulties are likely to be even more overwhelming in complex cases, which usually present with more ambiguous clinical manifestations; this may underline the finding that the effect of interruption in speeding up the diagnostic process was apparently stronger in complex cases.

By speeding up decision-making, interruption apparently prevented a more elaborate analysis of case features, thereby hindering the verification of initial diagnostic hypotheses and causing errors. Contrary to our expectations, the detrimental effect of interruption on the quality of diagnoses occurred not only when cases were complex but also in simple cases. We expected interruption to speed up the diagnostic process, leading doctors to rely more on initial judgments made through non-analytic, pattern-recognition-based reasoning. However, cognitive theories about human memory propose that such errors may arise from Type 1 and Type 2 reasoning. Errors in Type 1 reasoning may be a consequence of the associative nature of memory, which can lead to cognitive biases. [21] The management reasoning reflects iterative, back-and-forth involvement of both Type 1 (non-analytic, effortless) and Type 2 (analytic, effortful) thinking. [22] Previous studies have shown, however, that non-analytic reasoning works quite well in routine problems [18, 23] And, therefore, interruptions would not necessarily have negative consequences for the diagnosis of simple cases. It may have happened, however, that in our study, interruption took place so early in the diagnostic process that it hampered even non-analytical reasoning. In our study, participants were interrupted 20 seconds after they started reading the case, which may be too short for them to have encountered findings that would trigger appropriate pattern recognition.

Previous studies have explored the effect of interruptions on patient safety in the operating room [7, 9] and treatment-related procedures such as blood transfusion. [12] It is known that interruptions may lead to errors in medication dispensing. [6, 13] Our study focused not on procedural tasks but on doctors' diagnostic reasoning. The findings showed that interruptions also affect the diagnostic process and may cause diagnostic errors. Interruptions interfere with speeding up decisions, leading to premature closure, which has been identified as an important cause of diagnostic error. [24, 25] These findings support the

studies on the effects of healthcare working conditions, which emphasize the need to minimize interruptions and distractions to reduce mistakes. [6] Physicians are often interrupted during their duty time, for example, for emergency calls or consultations by nurses, co-patients, or students seeking advice. [26, 27] Suppose interruptions are so prevalent in clinical settings that they may negatively affect physicians' reasoning and diagnostic performance. In that case, our findings suggest that there may be serious consequences for patient safety.

The study limitations involve, first, the scarce clinical experience of the participants. More experienced physicians may have developed approaches to face interruptions without so much disturbance to the diagnostic process. However, as cognitive functions tend to deteriorate with age [28, 29], older doctors may have more difficulties resuming case processing. Second, the study removed the participants from their actual context to work on a computer-based task, with case scenarios and not real patients. This experimental approach is essential to investigating causal relationships, which require cautiousness in generalizing the findings to real clinical settings. It might be realized that interruptions in real settings might be even more pervasive and potentially more distracting than the ones used in this experiment.

Conclusions

The study provided experimental evidence that interruptions during the diagnostic process cause doctors to speed up diagnostic decisions, causing diagnostic errors. Interruptions affect the diagnosis of both simple and complex clinical cases and may be a threat to patient safety.

To date, little is known about effectively managing or minimizing interruptions and distractions in clinical settings. Health services research should investigate strategies that managers can use to minimize or avoid interruptions to clinicians from staying focused on their work. From the point of view of the individual doctor, it needs to be studied whether there are existing approaches to increase a clinician's ability to reduce the effects of interruptions in the work environment. This would require a better understanding of the mechanisms underlying the negative effects of interruptions on physicians' reasoning. Our study was just a first step; further investigation is a must.

Declarations

Declarations of Ethics approval and consent to participate.

Ethics approval was obtained from the Research Committee Ethics Board at King Abdulaziz Medical City (KAMC) in Riyadh, Saudi Arabia. All study methods adhered to the Ethical Guidelines for Medical and Health Research Involving Human Subjects. The principal investigator informed participants about the experiment and obtained written consent.

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Authors contributions

Nasreldin Ahmed had full access to all the study data and was responsible for the integrity of data analysis and accuracy.

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