Ben Thompson*, Christopher R. Madan and Rakesh Patel

# Investigating cognitive factors and diagnostic error in a presentation of complicated multisystem disease

https://doi.org/10.1515/dx-2021-0072
Received May 29, 2021; accepted October 6, 2021;
published online December 1, 2021

**Abstract**

**Objectives:** To use a case review approach for investigating the types of cognitive error identifiable following a complicated patient admission with a multisystem disorder in an acute care setting where diagnosis was difficult and delayed.
**Methods:** A case notes review was undertaken to explore the cognitive factors associated with diagnostic error in the case of an 18-year-old male presenting acutely unwell with myalgia, anorexia and vomiting. Each clinical interaction was analysed and identified cognitive factors were categorised using a framework developed by Graber et al.
**Results:** Cognitive factors resulting in diagnostic errors most frequently occurred within the first five days of hospital admission. The most common were premature closure; failure to order or follow up an appropriate test; over-reliance on someone else's findings or opinion; overestimating or underestimating usefulness or salience of a finding, and; ineffective, incomplete or faulty history and physical examination. Cognitive factors were particularly frequent around transitions of care and patient transfers from one clinical area to another. The presence of senior staff did not necessarily mitigate against diagnostic error from cognitive factors demonstrated by junior staff or diagnostic errors made out-of-hours.
**Conclusions:** Cognitive factors are a significant cause of diagnostic error within the first five days after admission, especially around transitions of care between different clinical settings and providers. Medical education interventions need to ensure clinical reasoning training supports individuals and teams to develop effective strategies for mitigating cognitive factors when faced with uncertainty over complex patients presenting with nonspecific symptoms in order to reduce diagnostic error.

**Keywords:** cognitive error; diagnostic error; medical education.

***Corresponding author: Ben Thompson**, Critical Care Department, Nottingham University Hospitals NHS Trust, Nottingham, UK, E-mail: ben.thompson8@nhs.net. https://orcid.org/0000-0003-3464-9759
**Christopher R. Madan,** School of Psychology, University of Nottingham, Nottingham, UK. https://orcid.org/0000-0003-3228-6501
**Rakesh Patel,** School of Medicine, University of Nottingham, Nottingham, UK; and Nottingham University Hospitals NHS Trust, Nottingham, UK. https://orcid.org/0000-0002-5770-328X

## Introduction

The diagnostic process is extraordinarily complicated at the best of times [1], however making a diagnosis and management plan in the face of uncertainty, when sick unwell patients present for medical attention, is a particular challenge for healthcare professionals in acute or emergency situations [2]. Evidence from the published literature confirms this challenge is a problem [3], given there can be a 20–40% discrepancy between antemortem and post-mortem diagnoses [4, 5]. The incidence of diagnostic error is reported around 10–15% [6], and even higher in specialities such as emergency and internal medicine. Given the scale of the problem, developing a standard approach to learning from cases where diagnostic error has occurred, or cases that have caused diagnostic dilemmas, also remains a priority [7].

Graber and colleagues undertook a systematic review of 100 case records constructing a taxonomy for factors operating across levels [8] with over three quarters involving cognitive contributions either alone or in combination with system level factors. Cognitive factors included a lack of knowledge or skill in general for a specific condition presenting in a particular context, and faults in the way individuals either processed, synthesised or verified information in the diagnostic process. In practice, these cognitive factors interact with system factors such as inefficient processes, poor teamwork or communications and a lack of coordination in care to result in diagnostic error. Although some system level challenges are beyond the scope of medical education, individual and team level factors, are within remit, since the main issues – cognitive factors such as a lack of knowledge or the processing, synthesis and verification of information – are trainable with interventions [9].

Whilst educators and researchers may have a good sense of cognitive factors associated with diagnostic error in classroom settings, the clinical context is different and the way in which working in clinical practice with complexity and uncertainty contributes to the problem remains poorly characterised. In particular, certain patient presentations where the clinical condition is fast evolving and the clinical picture is ambiguous can add to the diagnostic challenge resulting in error. Here the challenge for educators and researchers is to better familiarise themselves with complicated case presentations so interventions for knowledge or skills gaps can be addressed to increase resilience to diagnostic error in the future.

The aim of this research was to investigate the impact of cognitive factors in a case of delayed diagnosis following a complicated patient admission in acute care where the symptoms did not suggest an obvious cause at presentation to hospital. Although using case notes review for identifying aetiology of diagnostic error can be limited for certain aspects of the inquiry [6], this method remains the standard approach following significant incidents in hospitals and can still be useful for investigating the case-specific context in which cognitive factors resulting in diagnostic error were a problem. Furthermore, case reviews can be triangulated with outputs from other analyses [10], and serve as an important precursor for designing educational interventions such as simulations involving standardised patients for reducing future error.

## Clinical case

An 18-year-old, previously healthy, white male was admitted to the Medical Admissions Unit (MAU) in July 2020, with a four-week history of fever, myalgia, anorexia, nausea and vomiting. Physical examination revealed a heart rate of 140 beats per minute, blood pressure 120/87 mmHg, $SpO_2$ 96% on 2 L $O_2$ via nasal cannulae and a temperature of 39 °C. Blood investigations revealed Hb 109 g/L (normal range 130–180 g/L), WCC 5.1 $10^9$/L (normal range 4.0–11.0 $10^9$/L), lymphocytes 0.9 $10^9$/L (normal range 1.5–4.5 $10^9$/L), CRP 72 mg/L (normal range <10 mg/L) and lactate 1.6 mmol/L (normal range 0.5–2.2 mmol/L). ECG showed sinus tachycardia. A diagnosis of SARS-CoV-2 viral pneumonia was made, and a differential of bacterial pneumonia was also considered. He was treated with intravenous piperacillin/tazobactam as per local guidelines for the treatment of suspected bacterial pneumonia. Serial SARS-CoV-2 RT-PCR tests were negative.

No pathogens were isolated from serial blood cultures. Computed tomography scanning of the chest, abdomen, and pelvis demonstrated bilateral pleural effusions and 13 cm splenomegaly. An echocardiogram demonstrated no evidence of endocarditis or cardiac dysfunction.

On day 3, he reported back pain, word finding difficulty, memory loss and urinary incontinence, and was noted on examination to have proximal weakness and a resting tremor. Non-contrast computed tomography scanning of the head demonstrated no abnormalities. He developed type 1 respiratory failure and agitation on day 6 necessitating transfer to the Intensive Care Unit (ICU) and intubation. Two intercostal drains were placed on either side of the chest for bilateral pleural effusions (Figure 1). Viral serology, fungal biomarkers and procalcitonin were negative.

Other investigations revealed a high ESR, ANA +ve (one in 6,400), dsDNA strongly positive, nephrotic range proteinuria with normal renal function, low C3 level 0.69 g/L (normal range 0.75–1.65 g/L), Crithidia positive but ENA negative. A diagnosis of systemic lupus erythematosus was made on day 10 and he was started on methylprednisolone and hydroxychloroquine. Following extubation on day 11, he developed hallucinations presumed secondary to high dose steroids. An MRI brain on day 17 demonstrated acute multi territory infarcts alongside vessel appearances consistent with SLE vasculitis therefore intravenous cyclophosphamide was added to his treatment regimen. A renal biopsy confirmed mesangioprolofierative glomerulonephritis consistent with class III lupus nephritis. Further

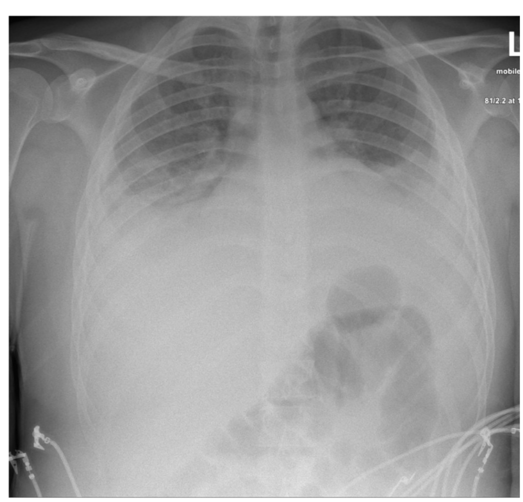

Figure 1: A portable anterior-posterior chest radiograph on day 6 of admission.

investigations were also positive for Anti-MI2, anti-KU, anti-PM-SCL75 and anti-SLP antibodies. Covid-19 antibody negative. His SLEDAI (Systemic Lupus Erythematosus Disease Activity Index) was 35.

He was discharged on day 30 and intravenous cyclophosphamide (pulsed regimen) was continued in the community. At six-week follow up, he had well controlled blood pressure, normal renal function and minimal urinary protein leak. His cognitive function was improved with a Montreal Cognitive Assessment score of 26 and his recovery including rehabilitation was ongoing.

# Materials and methods

## Methodology

A case review is a type of case-study approach for in-depth investigation of a complex issue in it's real-life context and informed the way this research was undertaken [11]. It is an established research design that has been used in a variety of disciplines [12]. A case has a defined space and time frame: a phenomenon in a bounded context [13]. The phenomena of cognitive factors contributing to diagnostic error are particularly context specific, therefore the case-study approach was deemed most suited [14]. Likewise, boundaries between a phenomenon and it's context are not always clear, therefore case-study designs rely on multiple sources for evidence [15].

## Data collection

The unit of analysis was defined as any patient-clinician interaction (individual or team) documented in case notes (paper or electronic). A standardised electronic data collection form was designed in Microsoft Excel (Microsoft Corporation, Redmond, USA) to collate – date, time, location, entry type, documented differential diagnosis and grade of the most senior clinician present at the interaction. Three clinicians (BT, IN and PR) reviewed and analysed each interaction together using the form.

First, clinicians documented to be present at each interaction were differentiated by grade into senior and junior medical staff. Second, junior medical staff were divided into Speciality Registrars, Advanced Clinical Practitioners (ACP) and Senior House Officers (SHO). Speciality Registrar referred to doctors with over four years of post-graduate experience. Senior medical staff just included consultants. ACPs were clinicians with a non-medical background such as nursing, who had completed a further Masters level qualification. SHO is a label given to doctors with 2–4 years of post-graduate experience and encompassed junior trainees, fellows and trust grade doctors not working at Specialty Registrar level. The patient had no interactions with Foundation Year doctors, those with less than two years of experience.

Third, after reviewing the case noted documentation, remaining data sources explored by the raters included: (a) chart observations (documentation recording temperature, respiratory rate, oxygen saturations, heart rate, blood pressure and urine output), (b) clinical requests for investigations, and (c) investigation results [16, 17]. An underlying assumption was that data collected in different ways would nonetheless lead to similar conclusions, therefore approaching the investigation using data from different sources would develop a multi-faceted and detailed representation of the phenomenon through triangulation.

Fourth, data in the data collection form was organised based on Graber et al.'s [8] framework for classifying system-related and cognitive contributions to diagnostic error. A free text justification for the classification made by raters was included on the data collection form to ensure transparency and allow scrutiny of the process as necessary. The impact of the error or contribution was not graded.

## Data analysis

A framework analysis approach comprising five further stages (familiarisation; identifying a thematic framework; indexing; charting; mapping and interpretation) was used to interpret each interaction. Theoretical frameworks related to both knowledge (novice-expert development and skills decay [18, 19]) and cognitive factors leading to diagnostic error (dual information-processing, cognitive biases and critical thinking [20–22]) were used to support any early inferences made about the cognitive factors. Likewise, emergent data specific to the context of the data (a complicated multisystem disorder presentation in the acute and emergency setting) was also used to make interpretations as part of a data-driven approach. By using both approaches, the usefulness of the original taxonomy within the domain of healthcare professions education, and not just healthcare, could also be established.

## Ethical considerations

Consent to collect and code data as described above was obtained from the patient involved, their consultant and the Critical Care Department. Detailed information about the case presentation or the hospital sites was not shared to avoid the risk of inadvertent disclosure of identities. Ethical permission was not required to undertake this study.

# Results

## Interactions

Between admission and diagnosis there were 70 clinical interactions over 10 days. There were 17 interactions on the Medical Admissions Unit, followed by 19 on the Level 1 unit and 34 on the Intensive Care Unit. Over the 70 interactions there were 89 contributions to diagnostic error, 70 of which were cognitive factors, the rate of which was higher within the first five days of the patient's admission (Figure 2). There were 19 system related factors contributing to diagnostic error, distributed throughout, six of which were related to technical failure and equipment. Table 1 and Figure 3 demonstrate that review by a consultant happened more frequently later on in the admission, whilst the

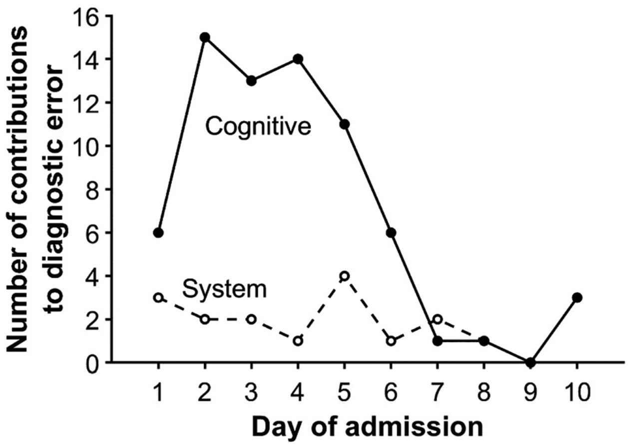


**Figure 2:** The number of contributions to diagnostic error on each day of admission.
Cognitive factors are shown as a solid line; system related factors are shown as dashed line. The patient was transferred from the medical admissions unit to Level 1 on day 4, and to the intensive care unit on day 6.

patient was on the ICU. The rate of contributions per interaction was lower with increasing grade of the most senior clinician present (Table 1).

## Cognitive factors

Figure 3 visualises the distribution of interactions and contributions to error throughout the patient's journey. Spikes in number of cognitive factors correlate with the identified most frequently occurring types described above. Of the 70 cognitive contributions to error identified across the interactions, they were not equally associated with the 25 possible types identified by Graber and used in taxonomy. Instead, the five most frequent cognitive factors accounted for 43 of these — thus comprising 61% of those identified. Each of these cognitive contributions to error were coded as occurring between 6 and 8 times, as shown in Figure 2. The most prevalent were (1) premature closure, (2) failure to order or follow up on an appropriate test, (3) overreliance on someone else's findings or opinion, (4) inaccurate estimation of the usefulness or salience of a finding, and (5) ineffective, incomplete or faulty history and physical exam. As apparent in Figure 3, these tended to co-occur with each other and coincided with the interactions where there was a spike in occurrences of cognitive contributions to error.

**Table 1:** The rate of contributions to diagnostic errors by area and grade.

| Rate (errors/ interactions) | SHO | ACP | Registrar | Consultant | Total |
|---|---|---|---|---|---|
| **MAU** | 2.83 (17/6) | 2.67 (8/3) | 1.67 (10/6) | 3.00 (6/2) | 2.41 (41/17) |
| **Level 1** | 2.50 (10/4) | – | 1.25 (15/12) | 2.00 (6/3) | 1.63 (31/19) |
| **ICU** | 0.57 (4/7) | – | 0.67 (6/9) | 0.39 (7/18) | 0.50 (17/34) |
| **Total** | 1.82 (31/17) | 2.67 (8/3) | 1.15 (31/27) | 0.83 (19/23) | 1.27 (89/70) |

Rate of contributions to diagnostic errors (number of contributions/number of interactions) by clinical area and grade of the most senior clinician present. MAU, medical admissions unit; ICU, intensive care unit; SHO, senior house officer; ACP, advanced clinical practitioner.

## Timeline

Clusters of error are associated with the transfer of the patient from one clinical area to another, specifically from the Medical Admission Unit to Level 1. There were seven main differential diagnoses documented in the clinical notes. The documented differential diagnoses changed following transfer, both to Level 1 and to ICU, also correlating with consultant presence at the interaction. At the second consultant review vasculitis was felt to be unlikely and subsequently vasculitis does not appear on the differential diagnosis for 2.9 days (71 h), the trigger for its return is the acknowledgement of a positive ANA on Day 6. At the first transfer, a new direction of investigation towards a spinal abscess was initiated based on a new differential diagnosis compared to the previous areas impression. This path is followed for two days (47 h), until the patient further deteriorated.

## Investigations

The time from admission to diagnosis was 8.7 days (210 h). There were time periods where access to information to rule in or rule out differentials was delayed. There were 23 h between a positive ANA result becoming available on the electronic records system and it being acted upon or acknowledged in the differential. An MRI spine was requested on day 4 to rule out concerns of a spinal abscess, due to issues surrounding availability it was not performed, in which time the patient deteriorated and was admitted to ICU. The investigation was cancelled at day 9 when it was felt that spinal abscess was not the primary differential. There were 50 h between the dsDNA request and a result becoming available. There was a delay of

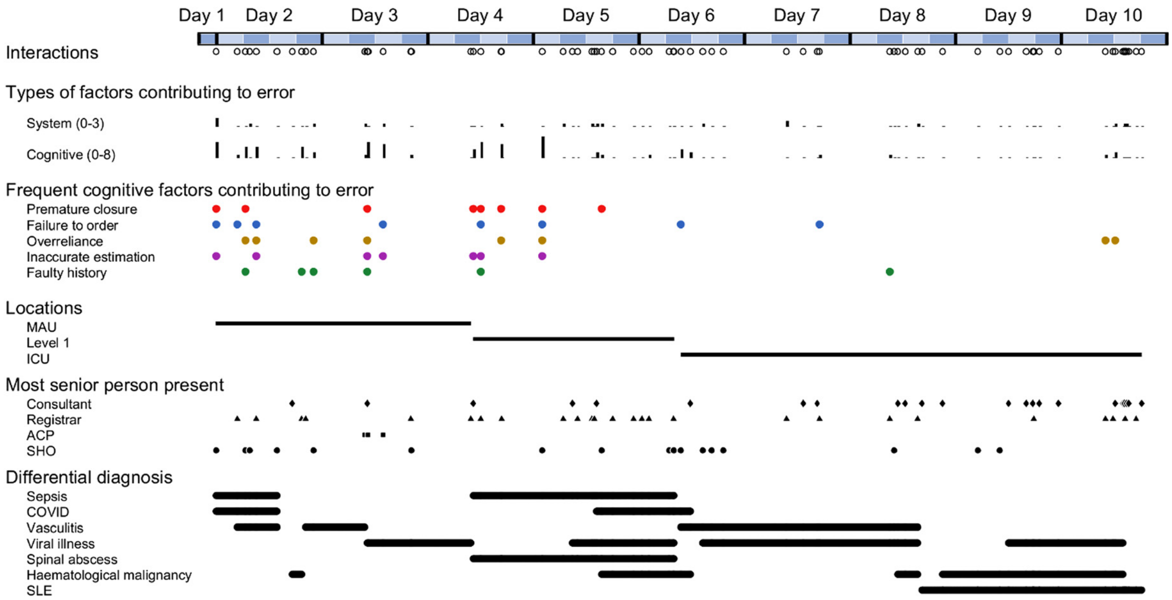


**Figure 3:** Timeline from admission to diagnosis.
Timeline with annotations of interactions, contributions to diagnostic error, clinical area, grade of the most senior clinician present and differential diagnosis. All interactions between admission at 23.50 on day 1 and definitive diagnosis and treatment at 18.15 on day 10 are indicated by hollow circles. The frequency of all coded factors contributing to error is indicated by vertical bar graph, differentiated by system and cognitive. The five most common cognitive factors contributing to error are indicated by coloured filled circles. The grade of the most senior clinician present at the interaction is indicated by black filled shapes. The differential diagnoses documented in the clinical notes is indicated by filled line. MAU, medical admissions unit; ICU, intensive care unit; SHO, senior house officer; ACP, advanced clinical practitioner.

approximately one day due to the first sample run failing due to a laboratory technical issue, this information being relayed back to the clinical team and a further sample being obtained.

## Discussion

This study investigated the impact of cognitive factors in the case of an 18-year-old presenting acutely unwell with non-specific signs and symptoms resulting in a delay in diagnosis. Whilst both system and cognitive factors contributed to diagnostic error, cognitive factors were more frequent until a definitive diagnosis was made. The range of cognitive factors are similar to those identified in previous research [23] with causes including: premature closure; failure to order or follow up on an appropriate test; over-reliance on someone else's findings or opinion; overestimating or underestimating usefulness or salience of a finding, and; ineffective, incomplete or faulty history and physical examination. However, this research also identified that diagnostic errors spiked around periods of transfer from one location to another, and suggested the presence of senior staff did not necessarily mitigate against errors made by junior staff or errors made out of hours. The findings from this case study have a number of implications for existing healthcare practice, medical education and training policy and further research into diagnostic error.

Research into cognitive factors affecting diagnosis in the clinical context is not new [24] however, a novel feature of this study was the investigation of cognitive factors and diagnostic error affecting the same patient as their care moved across multiple clinical areas, from the point of admission to the point of diagnosis. Errors in diagnostic reasoning is a recognised cause of error on internal medicine admissions units (MAU), with factors including failure to order correct tests; erroneous interpretation of tests; and failure to consider correct diagnoses [25]. In the emergency setting, 96% of diagnostic error was also attributed to cognitive factors [26]. Furthermore, over half of these errors were again related to a failure to order an appropriate test, with over a third of errors also related to a failure to perform an adequate medical history, physical examination or correctly interpret a diagnostic test [25]. Likewise, in ICU settings, misdiagnosis is also common within 12 h of admission and frequently occurs in presentations associated with infection or vascular events [27]. The findings from this research also have implications for other patients who present with non-specific signs and symptoms into hospital and may move through a number of clinical areas in a single admission episode. Patients with multimorbidity by definition often seek medical attention with problems that are not necessarily attributable to one disease process, therefore more research should be undertaken to identify the extent to which cognitive factors rather than disease complexity actually contribute to their well documented in-hospital morbidity and mortality [28].

There are well over hundred types of cognitive factors described [29], with many of them similar to each other or even leading to one another, for example search-satisficing and premature closure [21]. Nevertheless similar to the findings from this study, three error types consistently emerge from other empirical research and analyses of systematic reviews: availability, confirmation and hindsight bias [30]. Given hindsight bias affects any retrospective analyses, addressing the effect of availability and confirmation bias may be more appropriate for educators. Healthcare professionals are particularly prone to availability bias in complex and uncertain situations due to the paucity of information when making a diagnosis or management plan [31]. Therefore, the tendency for thinking to converge onto information that is available at the time is not unreasonable, and often necessary to manage acutely unwell patients [32]. However, the consequence of availability is individuals or teams being more prone to other cognitive factors such as search-satisficing, framing and confirmation [33] unless contextual cues related to the complicated nature of the presentation are recognised. Interventions that encourage both analytical and non-analytical processing have consistently been shown to improve diagnostic accuracy and minimise error in experimental settings [22]. Therefore, there is now a need for applying these insights from research into clinical practice when individuals or teams are faced with diagnostic dilemmas [9]. Specifically, novices need to be supported to use intuition when making diagnoses but also retain analytical approaches when ‘things aren't going as expected’. The challenge for both educators and hospital managers now moves onto nudging individuals and teams into applying these interventions at point of care.

Transfers from one care setting to another, ‘handoffs,’ are known to be associated with medical errors because the continuity of care is broken [34]. The findings from this research confirm both provider handoffs, wherein a different provider takes over the patient's care (e.g. shift change), and patient handoffs wherein the patient moves to a different clinical setting and provider, resulted in a spike of diagnostic errors following various cognitive factors. Handoff errors commonly result from communicating too little or too much information, failure to communicate high-risk status, incomplete transition of care responsibility, and failure to listen [35–38]. This research identified cognitive factors contributed to these outcomes in this case, with junior members of staff (e.g. SHO, ACP and Registrar) susceptible in particular. Against this backdrop, this research also demonstrated the presence of senior staff at daily reviews following transitions of care did not mitigate these cognitive factors. In particular, senior staff appeared to not effectively review differential diagnoses, nor mitigate against the lack of investigations available at the time of interactions, particularly following transfer from one setting to another. This observation is not new, with previous research also demonstrating failure or delay in considering a diagnosis as the most common error among physician self-reports of diagnostic error, and failure or delay in ordering a test and following up a test as the next frequent causes [39]. Furthermore, there also appears to have been little challenge between staff about changing differentials or pursing redundant ones within or across teams. Possible reasons include hierarchy barriers which are often implicit and known to exist across the care settings in this research and may prevent junior staff handing over work to others [40, 41]. As a consequence this research suggests educators should incorporate transition events into their teaching when creating case scenarios so not only clinical content is discussed, but also the thinking necessary for verifying the reasoning and decision-making rationale of colleagues following handover.

There are several implications for healthcare and healthcare education from this research. Firstly, clinical reasoning teaching needs to move beyond the individual arriving at their own diagnosis, and instead encourage individuals to calibrate their rationale when making a diagnosis with the thinking of others, especially when there is complexity and uncertainty [42, 43]. This is particularly important around the transitions of care, and teaching case scenarios should include features which provoke discussion about the cognitive factors which may influence diagnostic decision-making as well. Secondly, although the concept of the extended diagnostic team is gaining traction within healthcare [44] the roles and responsibilities of individuals within this new paradigm needs to be made explicit and trained so team members feel able to challenge any perceived cognitive factors despite the presence of a hierarchy or an authority gradient between individuals [33, 45, 46]. The surgical checklist has been transformative for patient safety outcomes in this regard [47], therefore a diagnostic decision-making checklist could be developed in a similar way empowering all members of the team to discuss and raise concerns about the influence of cognitive factors in where there is complexity and uncertainty. Finally, further research could also explore the way all individuals can leverage the collective wisdom of the team during daily reviews, ward rounds or handover events, to ensure they have not necessarily closed down their thinking too early or missed any outstanding tasks in between shifts. This would require educators to introduce the term 'cognitive factors' into clinical reasoning teaching as well as the incorporate the language used to communicate the various components into everyday teaching involving case scenarios as well.

A strength of this research was the case-study approach where individual interactions were analysed in depth to identify causes of cognitive error using a variety of data sources. This research also demonstrated the relative ease with which a taxonomy for categorising cognitive factors could be applied by three raters to a complicated multisystem disorder case presentation. A limitation of the research was that only a single case was considered and not other simple or complicated cases. Furthermore, there are now methods emerging which dissect down the elements of a case as part of a 'cognitive autopsy' which also demonstrate the multiplicative nature of cognitive factors both proximally and distally to each other [48]. This was not done as part of this research. Likewise, the limitations of case reviews for investigating diagnostic error are reported [6] therefore this study could have also explored re-creating the case presentation in a simulated setting to investigate the reproducibility of the errors identified at any given interaction if time and resource permitted.

**Acknowledgments:** We would like to thank Iyare Nehikhare and Portia Rhimes for their assistance in data collection and analysis.
**Research funding:** None declared.
**Author contributions:** All authors have accepted responsibility for the entire content of this manuscript and approved its submission.
**Competing interests:** Authors state no conflict of interest.
**Informed consent:** Informed consent was obtained from all individuals included in this study.
**Ethical approval:** Not applicable.

## References

1. Croskerry P. Adaptive expertise in medical decision making. Med Teach 2018;40:803–8.
2. Ilgen JS, Eva KW, de Bruin A, Cook DA, Regehr G. Comfort with uncertainty: reframing our conceptions of how clinicians navigate complex clinical situations. Adv Health Sci Educ 2019;24:797–809.
3. Leape LL, Brennan TA, Laird N, Lawthers AG, Localio AR, Barnes BA, et al. The nature of adverse events in hospitalized patients. N Engl J Med 1991;324:377–84.
4. Shojania KG, Burton EC, McDonald KM, Goldman L. Changes in rates of autopsy-detected diagnostic errors over time: a systematic review. J Am Med Assoc 2003;289:2849–56.
5. Graber M. Diagnostic errors in medicine: a case of neglect. Joint Comm J Qual Patient Saf 2005;31:106–13.
6. Graber ML. The incidence of diagnostic error in medicine. BMJ Qual Saf 2013;22:ii21–7.
7. Balogh EP, Miller BT, Ball JR. Improving diagnosis in health care. Washington, DC: National Academies Press; 2016:1–472 pp.
8. Graber ML, Franklin N, Gordon R. Diagnostic error in internal medicine. Arch Intern Med 2005;165:1493–9.
9. Durning SJ, Trowbridge RL, Schuwirth L. Clinical reasoning and diagnostic error: a call to merge two worlds to improve patient care. Acad Med 2020;95:1159–61.
10. Zwaan L, Singh H. The challenges in defining and measuring diagnostic error. Diagnosis (Berl). 2015;2:97–103.
11. Crowe S, Cresswell K, Robertson A, Huby G, Avery A, Sheikh A. The case study approach. BMC Med Res Methodol 2011;11:100.
12. Bunniss S, Kelly DR. Research paradigms in medical education research. Med Educ 2010;44:358–66.
13. Miles MB, Huberman AM, Saldana J. Qualitative data analysis: a methods sourcebook, 3rd ed. Thousand Oaks: SAGE Publications; 2019.
14. Norman G, Bordage G, Page G, Keane D. How specific is case specificity? Med Educ 2006;40:618–23.
15. Yin R, Campbell D. Case study research and applications: design and methods, 6th ed. Thousand Oaks: SAGE Publications; 2018.
16. Stake R. The art of case study research. Thousand Oaks: SAGE Publications; 1995.
17. Mays N, Pope C. Qualitative research in health care: assessing quality in qualitative research. Br Med J 2000;320:50–2.
18. Moulton CAE, Regehr G, Mylopoulos M, MacRae HM. Slowing down when you should: a new model of expert judgment. Acad Med 2007;82:S109–16.
19. Ericsson KA. Acquisition and maintenance of medical expertise: a perspective from the expert-performance approach with deliberate practice. Acad Med 2015;90:1471–86.
20. Croskerry P. A universal model of diagnostic reasoning. Acad Med 2009;84:1022–8.
21. Croskerry P, Singhal G, Mamede S. Cognitive debiasing 1: origins of bias and theory of debiasing. BMJ Qual Saf 2013;22:ii58–64.
22. Monteiro S, Sherbino J, Sibbald M, Norman G. Critical thinking, biases and dual processing: the enduring myth of generalisable skills. Med Educ 2020;54:66–73.
23. Norman GR, Eva KW. Diagnostic error and clinical reasoning. Med Educ 2010;44:94–100.
24. Croskerry P. The importance of cognitive errors in diagnosis and strategies to minimize them. Acad Med 2003;78:775–80.
25. Raffel KE, Kantor MA, Barish P, Esmaili A, Lim H, Xue F, et al. Prevalence and characterisation of diagnostic error among seven-day all-cause hospital medicine readmissions: a retrospective cohort study. BMJ Qual Saf 2020;29:971–9.
26. Kachalia A, Gandhi TK, Puopolo AL, Yoon C, Thomas EJ, Griffey R, et al. Missed and delayed diagnoses in the emergency

department: a study of closed malpractice claims from four liability insurers. Ann Emerg Med 2007;49:196–205.
27. Winters B, Custer J, Galvagno SM, Colantuoni E, Kapoor SG, Lee HW, et al. Diagnostic errors in the intensive care unit: a systematic review of autopsy studies. BMJ Qual Saf 2012;21: 894–902.
28. Mercer SW, Gunn J, Bower P, Wyke S, Guthrie B. Managing patients with mental and physical multimorbidity. BMJ 2012;345: e5559.
29. Wikipedia.org. List of cognitive biases [Internet]. Updated July 2021. https://en.wikipedia.org/wiki/List_of_cognitive_biases [Accessed Aug 2021].
30. Zwaan L, Monteiro S, Sherbino J, Ilgen J, Howey B, Norman G. Is bias in the eye of the beholder? A vignette study to assess recognition of cognitive biases in clinical case workups. BMJ Qual Saf 2017;26:104–10.
31. Mamede S, Van Gog T, Van Den Berge K, Rikers RMJP, Van Saase JLCM, Van Guldener C, et al. Effect of availability bias and reflective reasoning on diagnostic accuracy among internal medicine residents. JAMA, J Am Med Assoc 2010;304:1198–203.
32. Ilgen JS, Bowen JL, de Bruin ABH, Regehr G, Teunissen PW. “I was worried about the patient, but I wasn’t feeling worried”: how physicians judge their comfort in settings of uncertainty. Acad Med 2020;95:S67–72.
33. Ogdie AR, Reilly JB, Pang WG, Keddem S, Barg FK, Von Feldt JM, et al. Seen through their eyes: residents’ reflections on the cognitive and contextual components of diagnostic errors in medicine. Acad Med 2012;87:1361–7.
34. Cook RI, Render M, Woods DD. Gaps in the continuity of care and progress on patient safety. Br Med J 2000;320:791–4.
35. Raduma-Tomàs MA, Flin R, Yule S, Williams D. Doctors’ handovers in hospitals: a literature review. BMJ Qual Saf 2011;20:128–33.
36. Apker J, Mallak LA, Gibson SC. Communicating in the “gray zone”: perceptions about emergency physician-hospitalist handoffs and patient safety. Acad Emerg Med 2007;14:884–94.
37. Cheung DS, Kelly JJ, Beach C, Berkeley RP, Bitterman RA, Broida RI, et al. Improving handoffs in the emergency department. Ann Emerg Med 2010;55:171–80.
38. Riesenberg LA, Leitzsch J, Massucci JL, Jaeger J, Rosenfeld JC, Patow C, et al. Residents’ and attending physicians’ handoffs: a systematic review of the literature. Acad Med 2009;84:1775–87.
39. Schiff GD, Hasan O, Kim S, Abrams R, Cosby K, Lambert BL, et al. Diagnostic error in medicine: analysis of 583 physician-reported errors. Arch Intern Med 2009;169:1881–7.
40. Sexton B, Thomas E, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. Ugeskr Laeger 2000;162:2725.
41. Flowerdew L, Brown R, Vincent C, Woloshynowych M. Identifying nontechnical skills associated with safety in the emergency department: a scoping review of the literature. Ann Emerg Med 2012;59:386–94.
42. Fernandez R, Shah S, Rosenman ED, Kozlowski SWJ, Parker SH, Grand JA. Developing team cognition. Simulat Healthc 2017;12: 96–103.
43. Weaver SJ, Dy SM, Rosen MA. Team-training in healthcare: a narrative synthesis of the literature. BMJ Qual Saf 2014;23: 359–72.
44. Graber ML, Rusz D, Jones ML, Farm-Franks D, Jones B, Cyr Gluck J, et al. The new diagnostic team. Diagnosis (Berl). 2017;4:225–38.
45. Cosby KS, Croskerry P. Profiles in patient safety: authority gradients in medical error. Acad Emerg Med 2004;11:1341–5.
46. Schwappach DL, Gehring K. Trade-offs between voice and silence: a qualitative exploration of oncology staff’s decisions to speak up about safety concerns. BMC Health Serv Res 2014; 14:303.
47. Haynes A, Weiser T, Berry W, Lipsitz S, Breizat A, Dellinger E, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. N Engl J Med 2009;360:491–9.
48. Croskerry P. Our better angels and black boxes. Emerg Med J 2016;33:242–4.