BJCP British Journal of Clinical Pharmacology

DOI:10.1111/bcp.12332

Exploring the causes of junior doctors' prescribing mistakes: a qualitative study

Penny J. Lewis,[1] Darren M. Ashcroft,[1] Tim Dornan,[2] David Taylor,[3] Val Wass[4] & Mary P. Tully[1]

[1]Manchester Pharmacy School, Manchester Academic Health Sciences Centre, University of Manchester, Manchester, UK, [2]Department of Educational Development and Research, Maastricht University, Maastricht, The Netherlands, [3]Liverpool Medical School Education Research Group, University of Liverpool, School of Medicine, Liverpool and [4]School of medicine, Keele University, Staffordshire, UK

Correspondence
Dr Penny Lewis PhD Mpharm, Manchester Pharmacy School, Manchester Academic Health Sciences Centre, University of Manchester, Oxford Road, Manchester M13 9PT, UK.
Tel.: 00 44 161 275 1806
Fax: 00 44 161 275 2416
E-mail: penny.lewis@manchester.ac.uk

Keywords
critical incident technique, hospitalists, internship, medication errors, qualitative research

Received
16 January 2013

Accepted
20 January 2014

Accepted Article Published Online
11 February 2014

WHAT IS ALREADY KNOWN ABOUT THIS SUBJECT

- Prescribing errors are common and detrimental to patient care.
- Junior doctors are more likely than consultants to make a prescribing error.
- There is little research into the causes of errors. Therefore, the aim of this paper is to explore the causes of Foundation Year 1 doctors' prescribing mistakes.

WHAT THIS STUDY ADDS

- Knowledge-based mistakes arose from poor knowledge of practical aspects of prescribing and lack of support.
- Rule-based mistakes resulted from inappropriate application of knowledge and following erroneous routines or orders.
- Although knowledge and expertise played a role in mistakes, many inter-related factors contributed. Therefore multiple interventions are necessary.

AIMS

Prescribing errors are common and can be detrimental to patient care and costly. Junior doctors are more likely than consultants to make a prescribing error, yet there is only limited research into the causes of errors. The aim of this study was to explore the causes of prescribing mistakes made by doctors in their first year post graduation.

METHODS

As part of the EQUIP study, interviews using the critical incident technique were carried out with 30 newly qualified doctors. Participants were asked to discuss in detail any prescribing errors they had made. Participants were purposely sampled across a range of medical schools (18) and hospitals (15). A constant comparison approach was taken to analysis and Reason's model of accident causation was used to present the data.

RESULTS

More than half the errors discussed were prescribing mistakes (errors due to the correct execution of an incorrect plan). Knowledge-based mistakes (KBMs) appeared to arise from poor knowledge of practical aspects of prescribing such as dosing, whereas rule-based mistakes (RBMs) resulted from inappropriate application of knowledge. Multiple error-producing and latent conditions were described by participants for RBMs and KBMs. Poor/absent senior support and a fear of appearing incompetent occurred with KBMs. Following erroneous routines or seniors' orders were major contributory factors in RBMs.

CONCLUSIONS

Although individual factors such as knowledge and expertise played a role in prescribing mistakes, there were many perceived interrelated factors contributing to error. We conclude that multiple interventions are necessary to address these and further research is essential.

Introduction

Prescribing errors in hospitals are common, occurring in approximately 7% of orders, 2% of patient days and 50% of hospital admissions [1]. Within hospitals much of the prescription writing is carried out by junior doctors. Until recently, the exact error rate of this group of doctors has been unknown. However, recently we found that Foundation Year 1 (FY1)[1] doctors made errors in 8.6% (95% CI 8.2, 8.9) of the prescriptions they had written and that FY1 doctors were twice as likely as consultants to make a prescribing error [2].

Previous studies that have investigated the causes of prescribing errors report lack of drug knowledge [3–9], the working environment [4–6, 8–12], poor communication [3–5, 9, 13], complex patients [4, 5] (including polypharmacy [9]) and the low priority attached to prescribing [4, 5, 9] as contributing to prescribing errors. A systematic review we conducted into the causes of prescribing errors found that errors were multifactorial and lack of knowledge was only one causal factor amongst many [14].

Understanding where precisely errors occur in the prescribing decision process is an important first step in error prevention. The systems approach to error, as advocated by Reason [15], categorizes unsafe acts as slips, lapses, rule-based mistakes or knowledge-based mistakes but importantly takes into account certain 'error-producing conditions' that may predispose the prescriber to making an error, and 'latent conditions'. These are often design features of organizational systems that allow errors to manifest. Further explanation of Reason's model is given in the Box 1.

In order to explore error causality, it is important to distinguish between those errors arising from execution failures or from planning failures [15]. The former are failures in the execution of a good plan and are termed slips or lapses. A slip, for example, would be when a doctor writes down aminophylline instead of amitriptyline on a patient's drug card despite meaning to write the latter. Lapses are due to omission of a particular task, for instance forgetting to write the dose of a medication. Execution failures occur during automatic and routine tasks, and would be recognized as such by the executor if they have the opportunity to check their own work.

Planning failures are termed mistakes and are 'due to deficiencies or failures in the judgemental and/or inferential processes involved in the selection of an objective or specification of the means to achieve it' [15], i.e. there is a lack of or misapplication of knowledge. It is these 'mistakes' that are likely to occur with inexperience. Characteristics of knowledge-based mistakes (KBMs) and rule-based mistakes (RBMs) are given in Table 1. These two types of mistakes differ in the amount of conscious effort required to process a decision, using cognitive shortcuts gained from prior experience. Mistakes occurring at the knowledge-based level have required substantial cognitive input from the decision-maker who will have needed to work through the decision process step by step. In RBMs, prescribing rules and representative heuristics are used in order to reduce time and effort when making a decision. These heuristics, although useful and often successful, are prone to bias.

Mistakes are less well understood than execution failures [15]. They are more likely to go unnoticed at the time by the prescriber, even when checking their work, as the executor believes their chosen action is the right one. Therefore, they constitute a greater danger to patient care than execution failures, as they always require someone else to draw them to the attention of the prescriber [15].

Junior doctors' errors have been investigated by others [8–10]. However, no distinction was made between those that were execution failures and those that were planning failures. The aim of this paper is to explore the causes of FY1 doctors' prescribing mistakes (i.e. planning failures) by in-depth analysis of the course of individual erroneous

Box 1

Reason's model [39]

Errors are categorized into two main types; those that occur with the failure of execution of a good plan (execution failures) and those that arise from correct execution of an inappropriate or incorrect plan (planning failures). Failures to execute a good plan are termed slips and lapses. Correctly executing an incorrect plan is considered a mistake.

Mistakes are of two types; knowledge-based mistakes (KBMs) or rule-based mistakes (RBMs).

These unsafe acts, although at the sharp end of errors, are not the sole causal factors. 'Error-producing conditions' may predispose the prescriber to making an error, such as being busy or treating a patient with communication difficulties. Reason's model also describes 'latent conditions' which, although not a direct cause of errors themselves, are conditions such as previous decisions made by management or the design of organizational systems that allow errors to manifest. An example of a latent condition would be the design of an electronic prescribing system such that it allows the easy selection of two similarly spelled drugs. An error is also often the result of a failure of some defence designed to prevent errors from occurring.

[1]Foundation Year 1 is equivalent to an internship or residency i.e. the doctors have recently completed their undergraduate degree but do not yet have a license to practice fully.

Table 1

Characteristics of knowledge-based and rule-based mistakes (modified from Reason [15])

Knowledge-based mistakes	Rule-based mistakes
Problem solving activities	
Due to lack of knowledge	Due to misapplication of knowledge
Conscious cognitive processing: The person performing a task consciously thinks about how to carry out the task step by step as the task is novel (the person has no previous experience that they can draw upon)	Automatic cognitive processing: The person has some familiarity with the task due to prior experience or training and subsequently draws on experience or 'rules' that they had applied previously
Decision-making process slow	Decision-making process relatively quick
The level of expertise is relative to the amount of conscious cognitive processing required	The level of expertise is relative to the number of stored rules and ability to apply the correct one [40]
Example:	***Example:***
Prescribing Timentin© to a patient with a penicillin allergy as did not know Timentin was a penicillin (Interviewee 2)	Prescribing the routine laxative Movicol© to a patient without consideration of a potential obstruction which may precipitate perforation of the bowel (Interviewee 13)

prescribing decisions, allowing for the subsequent identification of areas for intervention to reduce the number and severity of prescribing errors.

Methods

Data collection

We carried out face-to-face in-depth interviews using the critical incident technique (CIT) [16] to collect empirical data about the causes of errors made by FY1 doctors. Participating FY1 doctors were asked prior to interview to identify any prescribing errors that they had made during the course of their work. A prescribing error was defined as *'when, as a result of a prescribing decision or prescription-writing process, there is an unintentional, significant reduction in the probability of treatment being timely and effective or increase in the risk of harm when compared with generally accepted practice.'* [17]

A topic guide based on the CIT and relevant literature was developed and is provided as an additional file. Specifically, errors were explored in detail during the interview, asking about the nature of the error(s), the situation in which it was made, reasons for making the error and their attitudes towards it. The second part of the interview schedule explored their attitudes towards the teaching about prescribing they had received at medical school and their experiences of training received in their current post. This approach to data collection provided a detailed account of doctors' prescribing decisions and was used because it 'does not collect opinions and estimates but obtains a record of specific behaviours' [16]. Interviews lasted from 20 min to 80 min and were conducted in a private area at the participant's place of work. Participants' informed consent was taken by PL prior to interview and all interviews were audio-recorded and transcribed verbatim.

Sampling and recruitment

A letter of invitation, participant information sheet and recruitment questionnaire was sent via email by foundation administrators within the Manchester and Mersey Deaneries. In addition, short recruitment presentations were conducted prior to existing training events. Purposive sampling of interviewees ensured a 'maximum variability' sample of FY1 doctors who had trained in a variety of medical schools and who worked in a variety of types of hospitals.

Analysis

The computer software program NVivo© was used to assist in the organization of the data. The active failure (the unsafe act on the part of the prescriber [18]), error-producing conditions and latent conditions for participants' individual mistakes were examined in detail using a constant comparison approach to data analysis [19]. A coding framework was developed based on interviewees' words and phrases.

Reason's model of accident causation [15] was used to categorize and present the data, as it was the most commonly used theoretical model when considering prescribing errors [3, 4, 6, 7].

In this study, we identified those errors that were either RBMs or KBMs. Such mistakes were differentiated from slips and lapses based on the prescriber's intention described in the interview, i.e. whether it was the correct execution of an inappropriate plan (mistake) or failure to execute a good plan (slips and lapses). Very occasionally, these types of error occurred in combination, so we categorized the description using the type of error most represented in the participant's recall of the incident, bearing this dual classification in mind during analysis. The classification process as to type of mistake was carried out independently for all errors by PL and MT (Table 2) and any disagreements resolved through discussion. Whether an error fell within the study's definition of prescribing error was also checked by PL and MT.

NHS Research Ethics Committee and management approvals were obtained for the study.

Results

Recruitment questionnaires were returned by 68 FY1 doctors, from whom 30 were purposely selected. 15 FY1 doctors were interviewed from seven teaching

Table 2

Classification scheme for knowledge-based and rule-based mistakes

Knowledge-based mistakes	Rule-based mistakes
The plan of action was erroneous but correctly executed	
Was the first time the doctor independently prescribed the drug	The doctor had some experience of prescribing the medication
The decision to prescribe was strongly deliberated with a need for active problem solving	The doctor applied a rule or heuristic i.e. decisions were made with more confidence and with less deliberation (less active problem solving) than with KBM

hospital trusts and 15 from eight district general hospitals, who had graduated from 18 UK medical schools. They discussed 85 prescribing errors, of which 18 were categorized as KBMs and 34 as RBMs. The remainder were mainly due to slips and lapses.

Active failures

The KBMs reported included prescribing the wrong dose of a drug, prescribing the wrong formulation of a drug, prescribing a drug that interacted with the patient's current medication amongst others.

The type of knowledge that the doctors' lacked was often practical knowledge of how to prescribe, rather than pharmacological knowledge. For example, doctors reported a deficiency in their knowledge of dosage, formulations, administration routes, timing of dosage, duration of antibiotic treatment and legal requirements of opiate prescriptions. Most doctors discussed how they were aware of their lack of knowledge at the time of prescribing. Interviewee 9 discussed an occasion where he was uncertain of the dose of morphine to prescribe to a patient in acute pain, leading him to make several mistakes along the way:

'Well I knew I was making the mistakes as I was going along. That's why I kept ringing them up [senior doctor] and making sure. And then when I finally did work out the dose I thought I'd better check it out with them in case it's wrong' Interviewee 9.

RBMs described by interviewees included prescribing the wrong dose of a drug, prescribing a drug to which the patient was allergic and prescribing a medication which was contra-indicated amongst others. Interviewee 28 explained why she had prescribed fluids containing potassium despite the fact that the patient was already taking Sando K©. Part of her explanation was that she assumed a nurse would flag up any potential problems such as duplication:

'I just didn't open the chart up to check . . . I wrongly assumed the staff would point out if they're already on potassium replacement therapy . . . I tend to prescribe you know normal saline followed by another normal saline with some potassium in and I tend to have the same sort of routine that I follow unless I know about the patient and I think I'd just prescribed it without thinking too much about it' Interviewee 28.

RBMs were not associated with a direct lack of knowledge but appeared to be associated with the doctors' lack of expertise in framing the clinical situation (i.e. understanding the nature of the problem and gathering the information necessary to make the correct decision). This led them to select a rule that they had applied previously, often many times, but which, in the current circumstances (e.g. patient condition, current treatment, allergy status), was incorrect. These decisions were often deemed '*low risk*' and doctors described that they thought they were '*dealing with a simple thing*' (Interviewee 13). These types of errors caused intense frustration for doctors, who discussed how they had applied common rules and '*automatic thinking*' despite possessing the necessary knowledge to make the correct decision:

'And I learnt it at medical school, but just when they start "can you write up the normal painkiller for somebody's patient?" you just don't think about it. You're just like, "oh yeah, paracetamol, ibuprofen", give it them, which is a bad pattern to get into, sort of automatic thinking' Interviewee 7.

One doctor discussed how she had not taken into account the patient's current medication when prescribing, thereby choosing a rule that was inappropriate:

'I started her on 20 mg of citalopram and, er, when the pharmacist came round the next day he queried why have I started her on citalopram when she's already on dosulepin . . . and I was like, mmm, that's a very good point . . . I think that was based on the fact I don't think I was quite aware of the medications that she was already on . . .' Interviewee 21.

It appeared that doctors had difficulty in linking knowledge, gleaned at medical school, to the clinical prescribing decision despite being '*told a million times not to do that*' (Interviewee 5). Furthermore, whatever prior knowledge a doctor possessed could be overridden by what was the 'norm' in a ward or speciality. Interviewee 1 had prescribed a statin and a macrolide to a patient and reflected on how he knew about the interaction but, because everyone else prescribed this combination on his previous rotation, he did not question his own actions:

'I mean, I knew that simvastatin can cause rhabdomyolysis and there's something to do with macrolides

and simvastatin but I didn't quite put two and two together because everyone used to do that' Interviewee 1.

Contra-indications and interactions were a particularly common theme within the reported RBMs, whereas KBMs were commonly associated with errors in dosage. RBMs, unlike KBMs, were more likely to reach the patient and were also more serious in nature. A key feature was that doctors '*thought they knew*' what they were doing, meaning the doctors did not actively check their decision. This belief and the automatic nature of the decision-process when using rules made self-detection difficult.

Despite being the active failures in KBMs and RBMs, lack of knowledge or expertise were not necessarily the main causes of doctors' errors. As demonstrated by the quotes above, the error-producing conditions and latent conditions associated with them were just as important.

Error-producing conditions

Several error-producing conditions emerged when exploring interviewees' descriptions of events leading up to their mistakes. Busyness and workload were commonly cited reasons for both KBMs and RBMs. Busyness was due to reasons such as covering more than one ward, feeling under pressure or working on call. FY1 trainees found ward rounds especially stressful, as they often had to carry out a number of tasks simultaneously. Several doctors discussed examples of errors that they had made during this time:

'The consultant had said on the ward round, you know, "Prescribe this," and you have, you're trying to hold the notes and hold the drug chart and hold everything and try and write ten things at once, . . . I mean, normally I would check the allergies before I prescribe, but . . . it gets really hectic on a ward round' Interviewee 18.

Being busy and working through the night caused doctors to be tired, allowing their decisions to be more readily influenced. One interviewee, who was asked by the nurses to prescribe fluids, subsequently applied the wrong rule and prescribed inappropriately, despite possessing the correct knowledge. Part of his explanation for the error was his willingness to capitulate when tired:

'I didn't ask for any medical history or anything like that . . . over the phone at three or four o'clock [in the morning] you just say yes to anything' Interviewee 25.

Despite sharing these similar characteristics, there were some differences in error-producing conditions. With KBMs, doctors were aware of their knowledge deficit at the time of the prescribing decision, unlike with RBMs, which led them to take one of two pathways: approach others for assistance or continue with the prescription despite uncertainty. Those doctors who sought help and advice usually approached someone more senior. Yet, problems were encountered when senior doctors did not communicate effectively, failed to provide essential information (usually due to their own busyness), or left doctors isolated:

'. . . you're bleeped to a ward, you're asked to do it and you don't know how to do it, so you bleep someone to ask them and they're stressed out and busy as well, so they're trying to tell you over the phone, they've got no knowledge of the patient . . .' Interviewee 6.

Prescribing advice that could have prevented KBMs could have been sought from pharmacists yet when starting a post this doctor described being unaware of hospital pharmacy services:

'. . . there was a number, I found it later . . . I wasn't ever aware there was like, a pharmacy helpline. . . .' Interviewee 22.

Latent conditions

Steep hierarchical structures within medical teams prevented doctors from seeking help or indeed receiving adequate help, highlighting the importance of the prevailing medical culture. This varied between specialities and accessing advice from seniors appeared to be more problematic for FY1 trainees working in surgical specialities. Interviewee 22, who worked on a surgical ward, described how, when he approached seniors for advice to prevent a KBM, he felt he was annoying them:

'Q: What made you think that you might be annoying them?
A: Er, just because they'd say, you know, first words'd be like, "Hi. Yeah, what is it?" you know, "I've scrubbed." That'll be like, sort of, the introduction, it wouldn't be, you know, "Any problems?" or anything like that . . . it just doesn't sound very approachable or friendly on the phone, you know. They just sound rather direct and, and that they were busy, I was inconveniencing them . . .' Interviewee 22.

Medical culture also influenced doctor's behaviours as they acted in ways that they felt were necessary in order to fit in. When exploring doctors' reasons for their KBMs they discussed how they had chosen not to seek advice or information for fear of looking incompetent, especially when new to a ward. Interviewee 2 below explained why he didn't check the dose of an antibiotic despite his uncertainty:

'I knew I should've looked it up cos I didn't really know it, but I, I think I just convinced myself I knew it because

I felt it was something that I should've known . . . because it is very easy to get caught up in, in being, you know, "Oh I'm a Doctor now, I know stuff," and with the pressure of people who are maybe, sort of, a little bit more senior than you thinking "what's wrong with him?" ' Interviewee 2.

This behaviour was described as subsiding with time, suggesting that it was their perception of culture that was the latent condition rather than the actual culture. This interviewee discussed how he eventually learned that it was acceptable to check information when prescribing:

'. . . I find it quite nice when Consultants open the BNF up in the ward rounds. And you think, well I'm not supposed to know every single medication there is, or the dose' Interviewee 16.

Medical culture also played a role in RBMs, resulting from deference to seniority and unquestioningly following the (incorrect) orders of senior doctors or experienced nursing staff. A good example of this was given by a doctor who felt relieved when a senior colleague came to help, but then prescribed an antibiotic to which the patient was allergic, despite having already noted the allergy:

'. . . the Registrar came, reviewed him and said, "No, no we should give Tazocin, penicillin." And, erm, by that stage I'd forgotten that he was penicillin allergic and I just wrote it on the chart without thinking. I say without thinking, cos it, I had thought of it already, but, erm, I suppose it was because of the security of thinking, "Gosh, someone's finally come to help me with this patient," I just, kind of, and did as I was told . . .' Interviewee 15.

Discussion

Our in-depth exploration of doctors' prescribing mistakes using the CIT revealed the complexity of prescribing mistakes. It is the first study to explore KBMs and RBMs in detail and the participation of FY1 doctors from a wide variety of backgrounds and from a range of prescribing environments adds credence to the findings.

Nevertheless, it is important to note that this study was not without limitations. The study relied upon self-report of errors by participants. However, the types of errors reported are comparable with those detected in studies of the prevalence of prescribing errors (systematic review [1]). When recounting past events, memory is often reconstructed rather than reproduced [20] meaning that participants might reconstruct past events in line with their current ideals and beliefs. It is also possible that the search for causes stops when the participant provides what are deemed acceptable explanations [21]. Attributional bias [22] could have meant that participants assigned failure to external factors rather than themselves. However, in the interviews, participants were often keen to accept blame personally and it was only through probing that external factors were brought to light. Collins *et al*. [23] have argued that self-blame is ingrained within the medical profession. Interviews are also prone to social desirability bias and participants may have responded in a way they perceived as being socially acceptable. Furthermore, when asked to recall their prescribing errors, participants may exhibit hindsight bias, exaggerating their ability to have predicted the event beforehand [24]. However, the effects of these limitations were reduced by use of the CIT, rather than simple interviewing, which prompted the interviewee to describe all events surrounding the error and base their responses on actual experiences.

Despite these limitations, self-identification of prescribing errors was a feasible approach to this topic. Our methodology allowed doctors to raise errors that had not been identified by anyone else (because they had already been self corrected) and those errors that were more unusual (therefore less likely to be identified by a pharmacist during a short data collection period), in addition to those errors that we identified during our prevalence study [2].

The application of Reason's framework for classifying errors proved to be a helpful way of interpreting the findings enabling us to deconstruct both KBM and RBMs. Our resultant findings established that KBMs and RBMs have similarities and differences. Table 3 lists their active failures, error-producing and latent conditions and summarizes some possible interventions that could be introduced to address them, which are discussed briefly below.

In KBMs, there was a lack of understanding of practical aspects of prescribing such as dosages, formulations and interactions. Poor knowledge of drug dosages has been cited as a frequent factor in prescribing errors [4–6]. RBMs, on the other hand, appeared to result from a lack of expertise in defining a problem leading to the subsequent triggering of inappropriate rules, selected on the basis of prior experience. This behaviour has been identified as a cause of diagnostic errors [22, 25]. Doctors had particular difficulty identifying contra-indications and requirements for dosage adjustments, despite often possessing the correct knowledge, a finding echoed by Dean *et al*. [4] Doctors, by their own admission, failed to connect pieces of information about the patient, the drug and the context. Furthermore, when making RBMs doctors did not consciously check their information gathering and decision-making, believing their decisions to be correct. This lack of awareness meant that, unlike with KBMs where doctors were consciously incompetent, doctors committing RBMs were unconsciously incompetent.

Table 3

Potential interventions targeting knowledge-based mistakes and rule based mistakes

		Potential interventions
Knowledge-based mistakes	Active failures	• Greater undergraduate emphasis on practice elements and more work placements • Deliberate practice of prescribing and use of references
	Error-producing conditions	• Introduction of standardized tools to improve communication inter and intra-professionally. • Observing the prescribing process from the view of other members of MDT and critically reviewing prescriptions • Increasing the visibility of pharmacy services
	Latent conditions	• Make 'checking' acceptable and good practice • Stressing the importance of learning in the medical team – message for consultant surgeons of their role in supporting and guiding junior doctors • Team training techniques to improve communication and reduce errors
Rule-based mistakes	Active failures	• Training doctors to use metacognition ('think about thinking') and awareness of cognitive biases • Systematic/ checklists/ second opinion • Deliberate practice of prescribing
	Error-producing conditions	• Training in the understanding of cognitive errors and factors contributing to human error • Deliberate practice – simulation-based team training- history taking, understanding of skills and competencies available in the team and using them effectively • Improved questioning skills, support of the novice into expert
	Latent conditions	• Flattened hierarchies • Improved questioning skills

Better training and experience in prescribing as a medical student might improve doctors' knowledge. However, it would be impossible for doctors to memorize all information regarding individual drugs. Directing efforts at improving doctors' information seeking skills might be more valuable. The World Health Organization and the British Pharmacological Society have published guidance for prescribers [26, 27], including steps or principles that should be followed. Yet some of these steps, such as taking into account the patient's medication history and considering individual factors that might influence the prescription choice, were clearly overlooked or overridden by external factors during the prescribing events described by these doctors. Poor training in prescribing skills was identified as a latent condition in a study of Australian junior doctors' prescribing errors [5]. The introduction of training that focuses not just on following guidelines, but also on the importance of following a routine that includes self-checking, might go some way to alleviate both types of mistakes.

Cognitive forcing strategies [28] are a specific debiasing technique that is designed to prevent clinicians from applying the inappropriate pattern recognition that was displayed by some doctors executing RBMs in this study. These strategies involve the doctor applying a metacognitive step and stepping back from the situation and reflecting, allowing them to avoid or minimize cognitive error [28] and 'invoking the conscious mind' [29]. This reflection or internal assessment can include 'reminding oneself of limitations and failing of memory, reminding oneself of problems in the past and seeing the wider picture' [28]. This process will also prevent anchoring (fixation on particular aspects of the problem, whilst ignoring other important aspects) [28]. Research is needed, however, as to the best way to use such strategies in the very busy and interruption-prone working environment of the junior doctor.

Decision-making can be adversely affected by time-pressure [30]. High workload, stress and busyness were implicated in both KBMs and RBMs, as found elsewhere [4, 5]. However, time-pressure impacted on KBMs and RBMs somewhat differently. Preceding a KBM, time-pressure led to doctors taking risks such as prescribing despite uncertainty. Preceding a RBM, they intuitively applied faulty, yet speedier, heuristics when faced with a prescribing decision. The time-pressure may have forced doctors to use heuristics, which under time-pressure are even more susceptible to cognitive biases [28].

Doctors were cognizant of their knowledge deficit when making KBMs, so the fact that resultant decisions were erroneous was due to poor or absent information-seeking behaviour (i.e. error-producing conditions) or failures in supportive defence mechanisms (i.e. latent conditions). Working alone without immediate access to support has been shown elsewhere to be especially problematic for doctors in surgical rather than medical posts [9, 31]. In a study exploring the social and cultural dynamics of prescribing in Australia, both lack of awareness of the communication needs of others (including medication doses) and lack of opportunity for junior doctors to voice their information needs were important factors in prescribing errors [32]. Team training techniques including good questioning skills, may go someway to improve communication and prevent errors [33]. Furthermore, the support that the pharmacy team can provide to doctors when prescribing needs to be clearly communicated to junior doctors at induction. In addition, a wish to appear competent is a known barrier to junior doctors seeking help [34] and

doctors in our study exhibited this behaviour, leading to KBMs, as has been found in other work [4, 13]. Understanding what drives this behaviour in junior doctors is an important aspect of improving the safety culture of hospital practice.

In this study, communication was problematic across the multi-disciplinary team (MDT) as doctors assumed that nurses provided information without need for prompting. Poor and inefficient communication is a commonly cited factor in error production [4, 5, 13]. It has been found elsewhere that communication problems occur in a third of all surgical team exchanges, leading to a reduction in patient safety [35]. Standardization of communication, so that everyone within a situation knows what is expected of them when communicating with others, has been found useful elsewhere in the clinical setting [36]. Greater understanding of the prescribing process from different perspectives of the MDT may allow prescribers to gain a more holistic view of the medication process.

Some of the latent conditions identified in this study appear deeply embedded within the medical culture. Steep hierarchical structures are known to make prescribing decisions uncomfortable for junior doctors [37] but this study demonstrated that this structure is also one of many precursors to error. An in-depth analysis of a serious knowledge-based prescribing mistake by Patterson and colleagues [13] highlighted how such structures play a role in error causation.

Specifically, several doctors in this study felt that senior doctors were unapproachable or unhelpful, but comparable data on the thoughts and actions of their seniors were not available. However, junior doctors in a study by Duncan *et al*. highlighted similar issues [8]. Further research exploring the relationship between doctors in the hospital hierarchy might shed more light on this complex matter. The medical culture meant that relatively junior doctors often acted unquestionably on senior doctors' orders, even when those orders were incorrect. This implicit trust is an international phenomenon associated with the emergence of errors [5]. It was also found that doctor's knowledge could be overridden by the norm and that inappropriate prescribing could be passed down from senior colleagues [37, 38].

In conclusion, this study has enabled us to unpack the factors implicated in junior doctors' prescribing mistakes. We have demonstrated that, although individual factors, such as knowledge and expertise played a role in prescribing mistakes, there were many interrelated factors that contrib,uted to error. The findings show that KBM and RBMs shared some similar factors in their causality yet they were also quite different. RBMs were perhaps more important to safety than KBMs, being more likely to reach the patient. In order to be successful, attempts to reduce errors should remain cognisant of the complex nature of prescribing mistakes. Multiple and complex interventions may have to be implemented in order tackle both knowledge-based and rule-based mistakes – one size certainly does not fit all.

Ethical approval

The study obtained ethical approval from North Manchester Research Ethics Committee, O7/H1006/93. All participants gave informed consent before taking part.

Funding

This work was supported by the General Medical Council to contribute to the evidence base informing policy developments. The study funders had no role in the study design, in the collection, analysis, and interpretation of data, in the writing of this manuscript or in the decision to submit the article for publication.

Competing Interests

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare all authors had grant funding for the submitted work from the GMC, DA has received funding unrelated to this submitted work to cover expenses to deliver a lecture at the European Society of Clinical Pharmacy (ESCP) conference 2011, MT received an honorarium (£25) as well as funding to cover travel and accommodation from the Royal Society of Medicine to deliver a lecture 'Prescribing errors by Foundation Year 1 trainees' as well as receiving support from ISoft for travel to give a lecture on 'Research and Education – Prescribing Errors', MT received Travel/accommodation/meeting expenses unrelated to this submitted work from the Congress of South American Network of Pharmaceutical Care to deliver a lecture on pharmacist prescribing, TD received travel expenses from ISoft to deliver a lecture, no financial relationships with any organizations that might have an interest in the submitted work in the previous 3 years and no other relationships or activities that could appear to have influenced the submitted work.

We would like to thank all of the doctors who gave up their time to take part in this study.

REFERENCES

1 Lewis PJ, Dornan T, Taylor D, Tully MP, Wass V, Ashcroft DM. Prevalence, incidence and nature of prescribing errors in hospital inpatients: a systematic review. Drug Saf 2009; 32: 379–89.

2 Dornan T, Ashcroft DM, Heathfield H, Lewis PJ, Miles J, Taylor D, Tully MP, Wass V. An in depth investigation into the causes of prescribing errors by foundation trainees in relation to their medical education. EQUIP study. 2009.

3 Kopp BJ, Erstad BL, Allen ME, Theodorou AA, Priestley G. Medication errors and adverse drug events in an intensive care unit: direct observation approach for detection. Crit Care Med 2006; 34: 415–25.

4 Dean B, Schachter M, Vincent C, Barber N. Causes of prescribing errors in hospital inpatients: a prospective study. Lancet 2002; 359: 1373–8.

5 Coombes ID, Stowasser DA, Coombes JA, Mitchell C. Why do interns make prescribing errors? A qualitative study. Med J Aust 2008; 188: 89–94.

6 Leape LL, Bates DW, Cullen DJ, Cooper J, Demonaco HJ, Gallivan T, Hallisey R, Ives J, Laird N, Laffel G. Systems analysis of adverse drug events. ADE Prevention Study Group. JAMA 1995; 274: 35–43.

7 Buckley MS, Erstad BL, Kopp BJ, Theodorou AA, Priestley G. Direct observation approach for detecting medication errors and adverse drug events in a pediatric intensive care unit. Pediatr Crit Care Med 2007; 8: 145–52.

8 Duncan EM, Francis JJ, Johnston M, Davey P, Maxwell S, McKay GA, McLay J, Ross S, Ryan C, Webb DJ, Bond C. Learning curves, taking instructions, and patient safety: using a theoretical domains framework in an interview study to investigate prescribing errors among trainee doctors. Implement Sci 2012; 7: 86.

9 Ross S, Ryan C, Duncan EM, Francis JJ, Johnston M, Ker JS, Lee AJ, Macleod MJ, Maxwell S, McKay G, McLay J, Webb DJ, Bond C. Perceived causes of prescribing errors by junior doctors in hospital inpatients: a study from the PROTECT programme. BMJ Qual Saf 2013; 22: 97–102.

10 Ryan C, Ross S, Davey P, Duncan EM, Fielding S, Francis JJ, Johnston M, Ker J, Le AJ, Macleod MJ, Maxwell S, McKay G, McLay J, Webb DJ, Bond C. Junior doctors' perceptions of their self-efficacy in prescribing, their prescribing errors and the possible causes of errors. Br J Clin Pharmacol 2013; 76: 980–7.

11 Lederman RM, Parkes C. Systems failure in hospitals – using reason's model to predict problems in a prescribing information system. J Med Syst 2005; 29: 33–43.

12 Parke J. Risk analysis of errors in prescribing, dispensing and administering medications within a district hospital. J Pharm Pract Res 2006; 36: 21–4.

13 Patterson ES, Cook RI, Woods DD, Render ML. Examining the complexity behind a medication error: generic patterns in communication. IEEE Trans Syst Man Cybern A Syst Hum 2004; 34: 749–56.

14 Tully MP, Ashcroft DM, Dornan T, Lewis PJ, Taylor D, Wass V. The causes of and factors associated with prescribing errors in hospital inpatients: a systematic review. Drug Saf 2009; 32: 819–36.

15 Reason J. Human Error. Cambridge: Cambridge University Press, 1990.

16 Flanagan JC. The critical incident technique. Psychol Bull 1954; 51: 327–58.

17 Dean B, Barber N, Schachter M. What is a prescribing error? Qual Health Care 2000; 9: 232–7.

18 Reason J. Beyond the organisational accident: the need for 'error wisdom' on the frontline. Qual Saf Health Care 2004; 13: (Suppl. 2): ii28–ii33.

19 Pope C, Ziebland S, Mays N. Qualitative research in health care. Analysing qualitative data. BMJ 2000; 320: 114–6.

20 Bartlett FC. Remembering: An Experimental and Social Study. Cambridge: Cambridge University Press, 1932.

21 Rasmussen J. Human error and the problem of causality in analysis of accidents. Philos Trans R Soc Lond B Biol Sci 1990; 327: 449–60.

22 Croskerry P. Achieving quality in clinical decision making: cognitive strategies and detection of bias. Acad Emerg Med 2002; 9: 1184–204.

23 Collins ME, Block SD, Arnold RM, Christakis NA. On the prospects for a blame-free medical culture. Soc Sci Med 2009; 69: 1287–90.

24 Henriksen K, Kaplan H. Hindsight bias, outcome knowledge and adaptive learning. Qual Saf Health Care 2003; 12: (Suppl. 2): ii46–ii50.

25 Norman GR, Eva KW. Diagnostic error and clinical reasoning. Med Educ 2010; 44: 94–100.

26 British Pharmacological Society. Ten Principles of Good Prescribing. London: British Pharmacological Society, 2010.

27 World Health Organization. Guide to Good Prescribing. A Practical Manual. 1994. Geneva: WHO, 2012.

28 Croskerry P. Cognitive forcing strategies in clinical decisionmaking. Ann Emerg Med 2003; 41: 110–20.

29 Graber ML. Educational strategies to reduce diagnostic error: can you teach this stuff? Adv Health Sci Educ Theory Pract 2009; 14: (Suppl. 1): 63–9.

30 Edland A, Svensin O. Judgement and decision making under time pressure. In: Time Pressure and Stress in Human Judgement and Decision Making, eds Svenson O, Maule AJ. New York: Plenum press, 1993; 27–40.

31 Goldacre MJ, Davidson JM, Lambert TW. Doctors' views of their first year of medical work and postgraduate training in the UK: questionnaire survey. Med Educ 2003; 37: 802–8.

32 Page MA, Bajoreck BV, Brien JA. Prescribing in teaching hospitals: a qualitative study of social and cultural dynamics. J Pharm Pract Res 2008; 38: 286–91.

33 Morey JC, Simon R, Jay GD, Wears RL, Salisbury M, Dukes KA, Berns SD. Error reduction and performance improvement in the emergency department through formal teamwork training: evaluation results of the MedTeams project. Health Serv Res 2002; 37: 1553–81.

34 Sutcliffe KM, Lewton E, Rosenthal MM. Communication failures: an insidious contributor to medical mishaps. Acad Med 2004; 79: 186–94.

35 Lingard L, Espin S, Whyte S, Regehr G, Baker GR, Reznick R, Bohnen J, Orser B, Doran D, Grober E. Communication failures in the operating room: an observational classification of recurrent types and effects. Qual Saf Health Care 2004; 13: 330–4.

36 Leonard M, Graham S, Bonacum D. The human factor: the critical importance of effective teamwork and communication in providing safe care. Qual Saf Health Care 2004; 13: (Suppl. 1): i85–i90.

37 Lewis PJ, Tully MP. Uncomfortable prescribing decisions in hospitals: the impact of teamwork. J R Soc Med 2009; 102: 481–8.

38 Pearson SA, Rolfe I, Smith T. Factors influencing prescribing: an intern's perspective. Med Educ 2002; 36: 781–7.

39 Reason J. Human error: models and management. BMJ 2000; 320: 768–70.

40 Ericsson KA. Deliberate practice and the acquisition and maintenance of expert performance in medicine and related domains. Acad Med 2004; 79: (Suppl. 10): S70–S81.