BEHAVIOURAL DESIGN FOR MEDICAL ERRORS DURING PATIENT DIAGNOSIS PROCESS

Dey, Swagatam;
Dabral, Shweta;
Khadilkar, Pramod

Indian Institute of Technology, Delhi

ABSTRACT

The health and well-being sector has been of significant interest to the behavioural design domain since bringing in behavioural changes can help improve the overall well-being of a community. However, the domain's intervention in this sector has been limited to persuasive techniques for the adoption of healthier lifestyles. There is a need to consider the diagnostic actions and decisions undertaken by doctors as it represents an important part of health and well-being improvement of people. Medical errors committed by healthcare professionals are an important aspect of the healthcare domain. Since these errors result due to undesired or non-normative behaviours, behavioural design can be instrumental in their eradication. But the research on integrating behavioural design and medical error literature is still nascent.

In this paper, we address this gap by identifying the categories of errors based on the performance levels within which they occur. Next, we contextualise these errors categories to medical literature focusing on the diagnostic stage. We further link it to the behavioural change model of COM-B to determine preliminary intervention functions that can be utilised by behavioural designers to deploy interventions.

Keywords: Medical Errors, Behavioural Design, Decision making, Design methods, Social responsibility

Contact:
Dey, Swagatam
Indian Institute of Technology
India
swagatam.dey@design.iitd.ac.in

Cite this article: Dey, S., Dabral, S., Khadilkar, P. (2023) 'Behavioural Design for Medical Errors during Patient Diagnosis Process', in *Proceedings of the International Conference on Engineering Design (ICED23),* Bordeaux, France, 24-28 July 2023. DOI:10.1017/pds.2023.77

1 INTRODUCTION

The behavioural design domain in recent times has significantly promoted health-conscious and precautionary behaviours among individuals and communities alike. To achieve this, the domain integrates theories of cognitive psychology, behavioural science, and design to create "behaviour-centric" interventions that promote desirable behaviours in areas like sexual health and contraception, smoking and healthy dietary and exercising habits (Bay Brix Nielsen *et al.*, 2021; Cowdell and Dyson, 2019; Khadilkar and Cash, 2020). Nonetheless, with the onset of a disease, health depends largely on the doctor's ability to diagnose and treat it. Thus, the diagnostic ability of doctors plays a crucial role in any healthcare system. This is also a crucial area for behavioural designers because errors in these instances are essentially a result of "wrong or undesirable behaviours." These undesirable behaviours are either wrong plan formulation (problem-solving behaviour) or improper execution of well-formed action sequences (monitoring behaviour) (Reason, 1990). Predominantly, behavioural design interventions have mostly been limited to simpler actions like hand sterilisation, mask-wearing etc (Michie *et al.*, 2014). However, improving a doctor's diagnostic ability from a behavioural design perspective is limited (Schattner, 2021).

Patient diagnosis heavily influences the doctor's certainty in postulating a patient's illness (Bornstein and Emler, 2001). From a behavioural perspective, diagnosis as a problematic behaviour is affected by three factors, first task characteristics (like varying ill-defined and ambiguous patient symptoms etc.); secondly context-dependent factors (like time pressure, resource, and organisation constraints etc.), thirdly human-related factors (like doctor's skills, fatigue levels, knowledge etc.) (Wears, 2009). This is especially true in emergency departments where healthcare professionals must react in split seconds, without complete medical information (Kalra, 2004). These factors make healthcare providers prone to diagnostic errors that detrimentally affect patient safety. Designers dealing with the design of artefacts in healthcare applications like information management software, process designs, patient report/form designs, medical device design and diagnostic aid designs etc. should thus understand these factors. For this paper, we majorly deal with the third factor, i.e., human-related factors that influence diagnostic errors. This is crucial for designers designing artefacts as well as behavioural designers since both can benefit from this understanding. While considerable work has been done to relate the effects of these factors on generic human task performance (Kahneman and Frederick, 2002; Norman, 1981; Rasmussen, 1982, 1983; Reason, 1990; Simon, 1972; Simon and Newell, 1958; Stanovich, 2009, 2018; Tversky and Kahneman, 1974), the implications of these findings have not been explicitly connected to behavioural change theories and models. Therefore, establishing these critical linkages for the design community is the main goal of this paper.

In this work, we attempted to address this goal using a two-part approach. First, we developed an understanding of the underlying cognitive mechanisms associated with generic human task performance and error formation. Then, we identified and integrated the existing human task performance and error classification frameworks available in the error literature to categorise the different types of diagnostic errors mentioned in the medical literature. This classification is extremely important since it provides an understanding of the causes and modes in which doctors can exhibit erroneous behaviours in a patient diagnostic process. Secondly, we mapped these error categories to the constructs of an established behavioural change model- COM-B (Michie *et al.*, 2014; West and Michie, 2020) to identify potential functions that need to be fulfilled by designed artefacts to effectively counter diagnostic errors.

2 SOURCES AND SELECTION CRITERIA

An integrative literature review was conducted in a two-phased manner to categorise diagnostic errors based on shared characteristics like causes, modality, underlying cognitive mechanisms etc (Snyder, 2019). In the first phase, we identified the types and underlying cognitive mechanisms of errors in a generic sense. Next, we identified and integrated the generic human task performance and error classification models and frameworks, to classify human errors as a foundation for the classification of diagnostic errors and to extract behavioural implications from them. The following keywords were utilised in Google scholar across all date ranges- "errors", "error types", "human errors", "reasoning approaches", "reasoning and decision making", and "monitoring tasks- problem-solving tasks".

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

In the second phase, we contextualised the findings of the first phase in the context of diagnosis by conducting a literature search across the databases of Google Scholar and PubMed using keywords like "Medical Errors", "Diagnostic Errors", "Adverse Events", "Adverse Drug Events", and "Sharp End Errors". This phase aimed to identify different cases of diagnostic errors recorded in the medical literature and situate them within the error categories identified in the first phase of the literature review. This phase was instrumental in determining the relevancy of each error category in diagnostic contexts. We mainly focused on the errors occurring at the individual and individual-technology interaction levels while system, organisation and policy level errors were excluded due to the limited scope of the study. A total of 60 papers were collected and based on the abstracts, 28 papers were reviewed. Among the 28 papers, 12 papers represented the first phase for generic error classifications while 16 papers were reviewed for the second phase to categorise diagnostic errors. For determining possible directions for interventions, we utilised the COM-B model developed by Michie et.al.(2014; 2020). Figure 1 provides a comprehensive depiction of the literature review process. A list of the papers that have been shortlisted and reviewed can be accessed at the Google sheet link- http://docs.google.com/spreadsheets/d/1d7N-3b9ZFR9Ik48kr6XOtHnLSI9vkJR1oX_TXZtFhzM/edit?usp=sharing

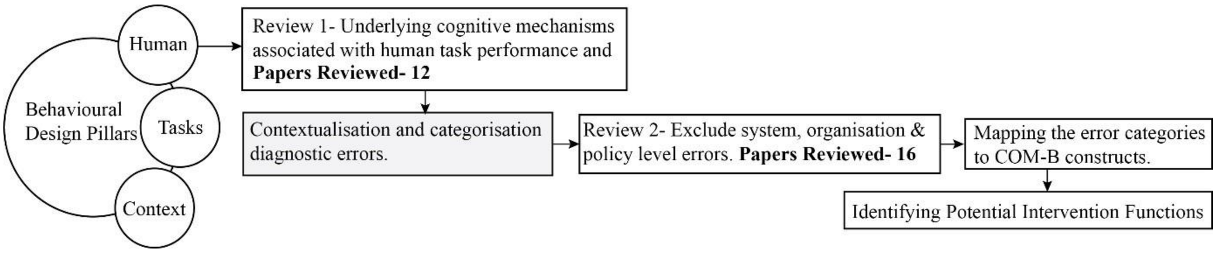

Figure 1. Literature review process

3 LITERATURE REVIEW

3.1 Human task performance levels and categories of error in diagnosis

Error is a broader term encompassing situations *"where a planned sequence of mental or physical activities fail to achieve the intended and desired outcome, and the cause of the failure can't be attributed to the intervention of any change agency"* (Reason, 1990, 2000). To understand the errors in diagnosis, defining the diagnostic process is important. It mainly consists of four main stages- presentation and perception formation, hypotheses generation, gathering and interpretation of evidence, and verification. During the presentation and perception formation stage, the doctor perceives the initial disease presentation of the patient (Croskerry, 2009a, 2009b; Pilnick *et al.*, 2009). In the hypotheses stage, various disease hypotheses are generated based on the perceived patient presentations (Kassirer and Kopelman, 1989). Further, pieces of evidence and tests are gathered and verified to establish the final diagnosis (Bornstein and Emler, 2001; Kassirer and Kopelman, 1989). There are two modes of error occurrences (Reason, 1990), first, 'problem-solving errors' that occur due to improper planning, i.e., based on hypothesis formation deciding on what tests to do, interpreting test reports to arrive at the diagnosis etc. Errors here occur while taking decisions about what actions to take. Second, 'monitoring or execution errors' are caused due to faulty execution of well-formed plans, e.g., a doctor measuring blood pressure or temperature without giving attention towards measurement or using an uncalibrated instrument. These errors depend on the doctor's physical and cognitive performance, referred to as task performance behaviours. Hence, understanding these during diagnosis is crucial. Literature review of 12 shortlisted papers identified four foundational frameworks for this purpose. This work has integrated the skill-rule-knowledge framework developed by (Rasmussen, 1983), the GEMS framework by Reason (1990, 2000), action slip categorisation by Norman (1981) and the hierarchical logic framework by Stanovich (2009, 2018) to explain the task performance behaviours and has situated the diagnostic errors in them.

The skill-rule-knowledge framework is used as an overall framework to explain the doctor's physical and cognitive behavioural performances. To identify and explain the modes and causes of errors occurring within each performance level, we utilised the GEMS framework, action slip categorisation and hierarchical logic framework proposed by Reason (1990), Norman (1981), and Stanovich (2009,

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

2018) respectively. Rasmussen (1983) proposes skill, rule, and knowledge-based performance levels. Doctors can exhibit the performance levels across all the diagnostic stages although the prevalence of one performance level might be higher than the others in a particular stage. For example, in the presentation and perception formation stage, the prevalence of skill-based performance is higher because the doctors utilise various artefacts like stethoscopes, and reports/notes to perceive and document patient's symptoms. Similarly, in the hypotheses generation stage, rule-based and knowledge-based level performance is more relevant due to the need for identifying possible disease hypotheses based on patient presentations. However, each performance level is accompanied by various errors that can jeopardize a patient's health during these stages of diagnosis (Blumenthal-Barby and Krieger, 2015; Graber *et al.*, 2005; Kopec *et al.*, 2003; Phua *et al.*, 2013). Next, we explain the three performance levels followed by the categories of error within each level. Further, we situate these error categories in diagnostic contexts by providing representative cases.

3.1.1 Skill-based behavioural performance level

This performance level consists of "*well-learned and highly integrated sensory-motor performances that are autonomously exhibited following the formation or identification of an intention*" (Rasmussen, 1983). These performances are mostly observable physical actions that are generated without much voluntary attention. The cognitive system responsible for these behaviours is referred to as System 1 (Kahneman and Frederick, 2002; Stanovich, 2009; Stanovich and Toplak, 2012).

The modality of errors at this level is monitoring failures that occur before the detection of a problem in a deterministic environment and are referred to as action slips and lapses wherein there is a failure to allocate the required attention leading to a non-normative execution of actions (Norman, 1981; Reason, 1990). Norman (1981) further provided the various forms of slips based on their causality-

- **Faulty intention formation-** These slips occur due to the misclassification of a situation and further exhibition of actions which can be ideal for the misclassified situation but are unsuitable for the actual situation. Such slips also occur when cues provided by the situation and the action sequences specified within a formed intention are ambiguous in nature.
- **Faulty activation of schemas-** These slips are characterised by unintentional activation of "schemas". This might occur due to a variety of reasons including attentional capture, and loss of the schema's ability to trigger due to blends and spoonerisms.
- **Faulty triggering of schemas-** These are error slips wherein even though the appropriate schema of action is selected and activated, it either triggers at the wrong time or does not trigger at all.

Representative cases of skill-based diagnostic errors identified in the literature.

- *Errors in the diagnostic procedures during an initial patient check-up, such as failing to wash hands before a patient examination, failing to wear a cap, gown, and gloves, failing to use sterile drapes properly, and sterile field violations* (Rothschild et al., 2005).

Here in all these cases, errors can occur owing to any of the causalities mentioned above. For example, the failure of a doctor to wash hands might be because of attentional capture by an irrelevant stimulus (faulty activation of schemas) or protocol to wash hands that are not remembered (faulty triggers).

3.1.2 Rule-based behavioural performance level

This is the first level of performance that people exhibit to solve problems. This is because people are strongly inclined towards finding “pre-packaged” solutions for the problem at hand owing to its less cognitive demand. They do this by comparing the cues within the external environment with the situational elements of stored problem-solving rules of the types: "*if (situation) then (system state), if (system state) then (remedial action)*" (Reason, 1990). In the case of diagnosis, this stage can be represented as when medical professionals must reason and decide on the diagnosis based on the patient's presentation. Schwartz and Elstein (2008) provided similar inferences when they found out that in familiar situations, professionals diagnose patients by utilising pattern-matching, heuristic, and other TASS (autonomic set of systems) based strategies (Stanovich, 2009) (see Figure 2). While this level is mostly autonomic and does not require much computational ability, recent evidence suggests that it is partly analytical and partly autonomous in nature (see page 69 of Stanovich, 2008). Post the detection of a problem, errors are collectively referred to as *problem-solving failures*.

Problem-solving errors at the rule-based level can occur when (Reason, 1990) -

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

- **There is a misapplication of well-formed rules in the wrong context-** This happens due to the over-weighing of signs (cues of the environment that agree with the application of the rule) above the countersigns (cues that disagree with the application of the rule) of a problem.
- **A bad rule is applied-** This happens when every cue of an environment is misrepresented or not encoded in the "if" section or when the action sequences of the rule i.e., the "then (remedial action)" yield inadequate or non-normative results.

Representative cases of rule-based diagnostic errors identified in the literature.

- *Case 1- A doctor diagnoses a patient with pneumonia based on findings like acute cough, night sweats and asymmetric respiration patterns however he neglects other absence of symptoms like the absence of chest pain and sinus tenderness that is indicative of the disease* (Bornstein and Emler, 2001).
- *Case 2- A patient goes to an emergency room complaining of chest pain brought on by a dissecting aneurysm. However, because myocardial ischemia is far more prevalent and hence more "accessible" in memory, the doctor may incorrectly believe that the patient has pain associated with myocardial ischemia and fail to recognise the dissecting aneurysms* (Graber et al., 2005).

In the first case, the signs of cough, night sweats and asymmetric respirations were weighed more than countersigns of the absence of chest pain and sinus which are essential for a pneumonia diagnosis. Here there were weighing biases involved in the doctor's diagnosis. This can be represented as a case where in there was a misapplication of well-formed rules. In the second case, due to recency and availability biases, a doctor applies the wrong rule of "if there is chest pain, it should be myocardial ischaemia".

3.1.3 Knowledge-based behavioural performance level

Knowledge-based performance is activated only when the existing repertoire of rules is not able to come up with a satisfactory response. This is characterised by its high computational demand and is mainly brought into use in novel situations for which new action sequences must be formulated. What differentiates this performance level from the other two is the cognitively demanding hypothetical thinking or system 2 thinking (Kahneman, 2000; Kahneman and Frederick, 2002) that is utilised to arrive at an optimal response. However, the activation of the level is dependent on higher level goal states and thinking dispositions of a person referred to as the reflective mind (Stanovich, 2009). When the reflective mind detects the formation of suboptimal responses and the need for overriding the responses with analytically formed optimal ones, it directs the algorithmic mind to engage in hypothetical thinking to generate an optimal response. To do so, the algorithmic mind must first inhibit the wrong responses generated by the previous autonomic process. Next, the algorithmic mind creates multiple "copies" or representations of the current state and then further hypothesises variations of those representations using already existing information called "mindware". However, to do so, it "decouples" multiple copies from the actual state to prevent misrepresentation. This process of decoupling and hypothesising multiple situations using mindware and further replacement of the incorrect response with the optimal response is known as a cognitive override. The override process generates a high cognitive load and hence this level of performance requires high computation capacity (Stanovich, 2009, 2018; Stanovich and Toplak, 2012). The underlying cognitive mechanism within this performance level is depicted in Figure 2.

To determine problem-solving errors at the knowledge-based level we utilised the hierarchical logic framework proposed by (Stanovich, 2018; Stanovich and West, 2008 because of its detailed explanation of the error types and causalities in the type 2 reasoning enforced knowledge-based level. Errors in this performance level are attributed to three types-

- **Unavailability of Mindware-** Occurs when the related mindware i.e., the declarative knowledge required to carry out an override sequence is absent, leading to a non-normative response.
- **Need for the override is undetected-** Error cases where even though related mindware to carry out an override is available a non-normative response is generated because the person does not detect any reason to carry out an override.
- **Incapability to override-** These errors are attributed to the absence of adequate cognitive capacity to carry out decoupling and hypothesis generation or simulation tasks.

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

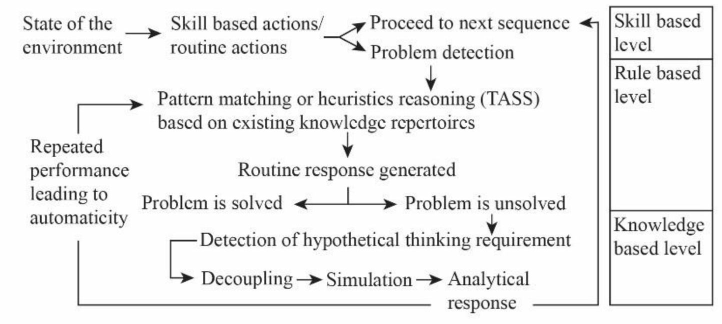

Figure 2. Underlying mechanisms across the three performance levels (author generated)

Representative cases of knowledge-based diagnostic errors identified in the literature.

- *Case 1- A 23-year-old woman with no prior medical history with a right-sided headache as well as left-sided clumsiness, weakness, and paresthesias reported to the emergency department. The exam noted a slight weakness on the left side. Complex migraine was diagnosed, and the patient was sent home following a negative head CT and a visit to the neurologist. When the patient returned two days later for more severe symptoms, a right thalamic and occipital infarct, as well as a patent foramen ovale, were discovered* (Dubosh et al., 2015).
- *Case 2- Due to constant distractions and an unusually busy schedule, a registrar misdiagnoses a patient with a pulmonary embolism for ischaemic heart disease. The decision of the registrar was "anchored" on the initial diagnosis proposed by a junior doctor and even though the patient reported other complaints, no differential diagnosis was considered* (Phua et al., 2013).

In the first case, based on the symptoms the patient was given a migraine diagnosis and sent home with ongoing symptoms since the doctors believed that given her age, a stroke was not likely to have occurred. Here the doctors lacked declarative knowledge about the probability of stroke in young individuals and the likelihood that an early stroke will result in a normal CT scan. In the second case, time pressure and cognitive stress disabled the doctor from analytically overriding the initial response generated through anchoring bias. This led to fatal consequences for the patient.

The three performance levels and error categorization inform designers about the errors but do not help in identifying probable strategies to mitigate these. The next section presents possible abstracted solution strategies referred to as intervention functions for mitigating these errors.

3.2 Identifying potential intervention functions using the COM-B model of behavioural change

The COM-B model introduced by Michie et.al. (2014; 2020) is an established model used for diagnosing the person/environment-based factors that need to be changed to achieve a target behaviour or to inhibit an undesired behaviour. The model proposes that behaviour depends on one's 'Capability', the 'Opportunity' presented by the physical and social environment, and one's 'Motivation' towards the behaviour (Michie *et al.*, 2014). Capability is a personal quality that makes a behaviour possible or facilitates it. Capability is increased by enhancing one's 'physical' capabilities like physique or musculoskeletal functioning or by 'psychological' capabilities like understanding, and knowledge repertoire of doctors regarding diseases etc. Opportunity is a property of an environment that enables or promotes a behaviour. Opportunities can be increased either by enhancing the material components of the physical environment (like patient reports and forms, electronic health record interfaces etc.) or by enhancing the social interactions between people and organisations (like organisational culture, norms etc.). These are called 'physical' and 'social' opportunities, respectively. Motivation is a collection of mental processes that enable and direct behaviours. Motivation enhancement can either be 'reflective' decided by rational processes or 'automatic' affected by past learnings, emotions, and habits (West and Michie, 2020). We utilise the COM-B model to further determine probable preliminary intervention functions to counter diagnostic errors.

3.2.1 Potential intervention functions for skill-based diagnostic errors

Faulty intention formation- Faulty intentions that lead to erroneous actions are caused when a diagnostic representation is misclassified or when the patient encounter does not emit the required cues to form the ideal intention or when the formed intention consists of ambiguous action sequences.

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

Therefore, to counter such errors, there is a need to either increase the environmental cues that enable ideal classification of the disease presentations (both social and physical opportunities) or reduce the ambiguity of action sequences carried out by the doctors (psychological capability) (refer to Figure 3). Based on Michie (2014), intervention functions like training programs (for example providing doctors with guidelines and precautionary measures) or enablement processes (for example providing checklists and guidelines and improving device interfaces) are most optimal for enhancing physical and social opportunities and psychological capabilities.

Faulty activation of schemas- Activation faults of schemas can either be due to unintentional activation and interruption of other schemas during action sequences where they are not needed, or ideal schemas lose their power of activation. In these cases, there is a need to increase the cognitive ability of the healthcare professional to focus on identifying the "schema breach" during performing a particular diagnostic action or remain attentive while doing so by removing unnecessary distractions (psychological capability). The case of loss of activation power of the schemas can also be countered by increasing the capability of an individual to memorise or utilise the schemas at the right moment (psychological capability) (see Figure 3 for the diagrammatic representation of the linkage). Intervention functions like training (for example self-regulation and monitoring, feedback, habit formation exercises) and education programs (for example providing doctors with guidelines and precautionary measures) can be optimal for such errors.

Faulty triggering of active schemas- These errors are characterised by improper or lack of triggering of the available schemas leading to wrong actions. Improper triggering of schemas is mainly attributable to the misclassification of external irrelevant stimuli which needs to be restricted. Ideal schemas might not trigger in the desired situation owing to a lack of required cues. These cases require the enhancement of opportunities for ideal triggers (social and physical opportunities) (Figure 3). For the first case, restrictive measures (like setting rules and regulations to reduce exposure to unnecessary distractions during initial doctor-patient interaction) are intervention functions of potential benefit. For lack of schema triggering, environmental restructuring (like adding prompts and cues in the environment and setting reminders) can be important.

In a skill-based performance, errors are related to automatic actions in nature and are not made after thorough consideration. As a result, such errors are unrelated to motivation.

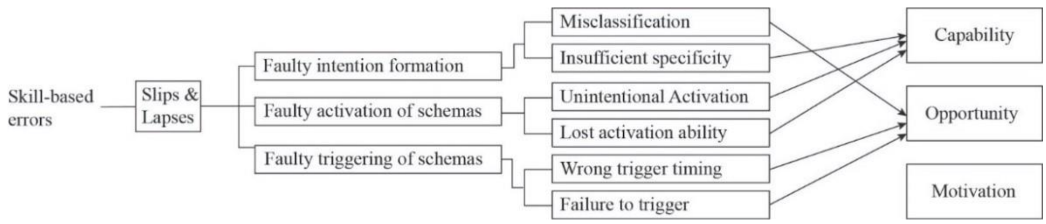

Figure 3. Diagrammatic representation of the linkage between skill-based errors and COM-B constructs

3.2.2 Potential intervention functions for rule-based diagnostic errors

Misapplication of good rules- Misapplication of well-formed rules occurs due to weighing biases wherein signs that agree with the application of the rule are given more weightage than the counter signs that disagree with the application. Such weighing biases can be reduced through behavioural regulations by increasing the capability (psychological capability) as well as the motivation (reflective motivation) of the doctor to compute both the signs and countersigns analytically (refer to Figure 4). Both psychological capability and reflective motivation, in this case, can potentially be enhanced by the intervention of the function of educational measures (like increasing the knowledge base of doctors to identify biased/ suboptimal responses and generating awareness to strengthen engagement towards analytical reasoning amongst doctors while diagnosing ambiguous cases).

Application of bad rules- Application of bad rules occurs when some cues of the doctor-patient interaction situation are misrepresented/ not represented at all within the conditional component (if) of a rule or when the action component (then) of the rule yields non-normative results. For the first case, there is a need to increase the representation of situational cues (physical opportunities) that can further help the doctor eliminate the chances of using a bad rule (refer to Figure 4). In the second case, there is a need to first increase the motivation (reflective motivation) towards improving the

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

metacognitive abilities to identify and inhibit the bad rule (see Figure 4). Physical opportunities in this case can be enhanced through the intervention function of enablement by introducing decisional heuristics like fast and frugal decision trees (Gigerenzer and Kurzenhauser, 2005) or improving imaging techniques and interfaces. Improvement of metacognitive abilities can be established by using the intervention functions of incentivisation (providing recognition to cases of effective diagnoses by doctors in complicated disease presentations) and persuasion programmes (like developing monitoring and evaluation approaches for diagnostic reasoning of doctors).

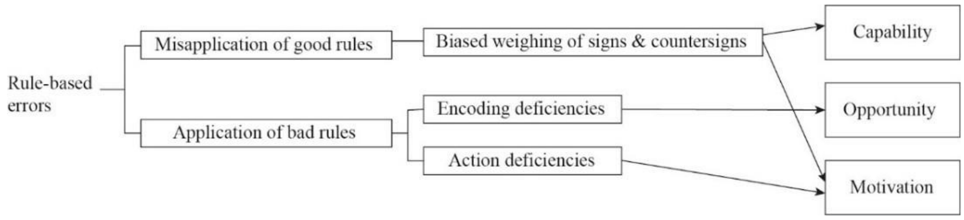

Figure 4. Diagrammatic representation of the linkage between rule-based errors and COM-B constructs

3.2.3 Potential intervention functions for knowledge-based diagnostic errors

Unavailability of mindware- These errors are attributed to the absence of relevant information with the doctor's knowledge repertoire required to detect the alternative optimal diagnosis over the suboptimal diagnosis generated. Based on the COM-B model, in this case, the doctor's existing repertoire of declarative knowledge needs to be enhanced (psychological capability) (see Figure 5). This can be done through the intervention function of educational programmes (like seminars and resources mentioning the prevalence of cardiovascular diseases among the young population etc.)

Need for the override is undetected- These errors are attributed to the absence of both internal mental and external environmental cues that establishes the need for generating an overriding sequence. These are diagnostic error cases wherein the declarative knowledge required to override a wrong diagnosis is present but the need for an override is not detected. To counter these errors, we need to increase the availability and visibility of cues for effective identification of the presence of normative diagnostic responses over the wrong response generated (physical opportunities) (refer to Figure 5). For this, the intervention function of enablement (like the development of feedback systems, decision support aids that nudge the doctors towards effective differential diagnosis etc.) is crucial.

Incapability to override- These errors are attributed to the lack of the doctor's cognitive ability to initiate the cognitive decoupling and simulation processes. Here, the need is to enhance or expand the cognitive ability (psychological capability) of the professional to do so as well as to consider the environment (physical and social opportunity) within which the professional is engaging in the cognitive processes (see Figure 5). While cognitive ability and social opportunity to decouple and simulate can be improved by enablement (like the development of effective decision support systems that reduce the cognitive load of the doctors, developing new interfaces to access and incorporate evidence-based data into the doctor's workflow), physical opportunity can be addressed through restrictions (like regulating working hours based physiological and psychological conditions of doctors).

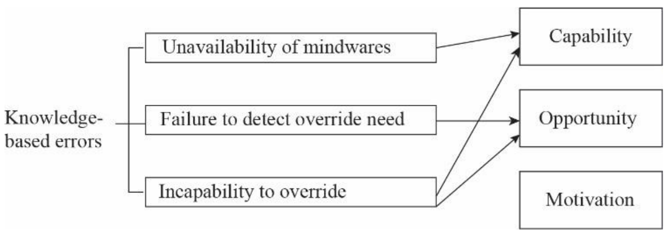

Figure 5. Diagrammatic representation of the linkage between knowledge-based errors and COM-B constructs

4 CONCLUSION

Diagnostic errors are human behaviours that can lead to adverse events for patients. The behavioural design, which intends to change problematic behaviours into desired behaviours, can be crucial in

https://doi.org/10.1017/pds.2023.77 Published online by Cambridge University Press

addressing diagnostic errors. This necessitates the development of literature that integrates the nuances of domains of human errors, diagnostic errors and behavioural design. This paper has used an integrative literature review to categorise the types, causes and fundamental cognitive mechanisms behind diagnostic errors by evolving from the foundational error literature. For this, we utilise the skill-rule-knowledge framework by Rasmussen, the GEMS framework by Reason, action slip categorisation by Norman, and the hierarchical logic framework proposed by Stanovich. We have first categorised the fundamental task performance behavioural levels of humans and the types of error categories associated with each level. Next, we situated cases of diagnostic errors found in the literature to elaborate and contextualise the performance levels and error categories identified in diagnostic literature. However, to make it useful for behavioural designers, this paper juxtaposes the error literature next to the most used behavioural model in the medical domain, the COM-B model of behaviour. This hints at what constructs of the COM-B model, i.e., Capabilities, Opportunities or Motivation, need support through behavioural interventions to reduce diagnostic errors. Further, abstract intervention ideas referred to as intervention functions associated with each COM-B construct have been briefly discussed. These suggestions are exploratory and initial to present a starting point for behavioural design practitioners to internalise the medical error literature using what they know. Importantly, there is a large body of literature related to COM-B that has successfully demonstrated the linkages between behavioural change techniques, intervention functions, and policy categories (Michie *et al.*, 2014; West and Michie, 2020) which could be utilized by the reader. The linkage of errors with COM-B constructs of behaviour change can easily be translated to complete deployable interventions using available literature. In the future, this integrative approach allows analyses of a real-use scenario to identify actual or possible errors, which could be translated into behavioural design interventions using COM-B. Another major scope is to situate more diagnostic error cases within the identified error categories for developing a nuanced understanding of the modalities of these errors. In absence of any existing bridging literature between medical errors and behavioural design, this work is crucial to building confidence in behavioural designers to venture into the domain of diagnostic errors.

REFERENCES

Bay Brix Nielsen, C.K.E., Daalhuizen, J. and Cash, P.J. (2021), "Defining the behavioural design space", International Journal of Design, Vol. 15 No. 1, pp. 1–16.

Blumenthal-Barby, J.S. and Krieger, H. (2015), "Cognitive biases and heuristics in medical decision making: A critical review using a systematic search strategy", Medical Decision Making, Vol. 35 No. 4, pp. 539–557. http://doi.org/10.1177/0272989X14547740.

Bornstein, B.H. and Emler, A.C. (2001), "Rationality in medical decision making: A review of the literature on doctors' decision-making biases", Journal of Evaluation in Clinical Practice, Vol. 7 No. 2, pp. 97–107. http://doi.org/10.1046/j.1365-2753.2001.00284.x.

Cowdell, F. and Dyson, J. (2019), "How is the theoretical domains framework applied to developing health behaviour interventions? A systematic search and narrative synthesis", BMC Public Health, Vol. 19 No. 1, pp. 1-10. http://doi.org/10.1186/s12889-019-7442-5.

Croskerry, P. (2009a), "Clinical cognition and diagnostic error: Applications of a dual process model of reasoning", Advances in Health Sciences Education, Vol. 14 No. 1, pp. 27–35. http://doi.org/10.1007/s10459-009-9182-2.

Croskerry, P. (2009b), "A Universal Model of Diagnostic Reasoning", Academic Medicine, Vol. 84 No. 8, pp. 1022-1028. http://doi.org/10.1097/acm.0b013e3181ace703.

Dubosh, N.M., Edlow, J.A., Lefton, M. and Pope, J. V. (2015), "Types of diagnostic errors in neurological emergencies in the emergency department", Diagnosis, Vol. 2 No. 1, pp. 21–28. http://doi.org/10.1515/dx-2014-0040.

Gigerenzer, G. and Kurzenhauser, S. (2005), "Fast and Frugal Heuristics in Medical Decision Making", in Bilbace, R., Laird, J.D., Kenneth, L.N. and Valsiner, J. (Eds.), Science and Medicine in Dialogue: Thinking through Particulars and Universals, Greenwood Publishing Group., Praeger Westport, Connecticut, pp. 3–15.

Graber, M.L., Franklin, N. and Gordon, R. (2005), "Diagnostic Error in Internal Medicine", Archives of Internal Medicine, Vol. 165 No. 13, pp. 1493-1499. http://doi.org/10.1001/archinte.165.13.1493.

Kahneman, D. (2000), "A psychological point of view: Violations of rational rules as a diagnostic of mental processes", Behavioral and Brain Sciences, Vol. 23 No. 5, pp. 681–683. http://doi.org/10.1017/S0140525X00403432.

Kahneman, D. and Frederick, S. (2002), "Representativeness Revisited: Attribute Substitution in Intuitive Judgment", Heuristics and Biases, Vol. 49, pp. 49–81. http://doi.org/10.1017/cbo9780511808098.004.

Kalra, J. (2004), “Medical errors: An introduction to concepts”, Clinical Biochemistry, Vol. 37 No. 12, pp. 1043–1051. http://doi.org/10.1016/j.clinbiochem.2004.08.007.
Kassirer, J.P. and Kopelman, R.I. (1989), “Cognitive errors in diagnosis: Instantiation, classification, and consequences”, The American Journal of Medicine, Vol. 86 No. 4, pp. 433–441. http://doi.org/10.1016/0002-9343(89)90342-2.
Khadilkar, P.R. and Cash, P. (2020), “Understanding behavioural design: barriers and enablers”, Journal of Engineering Design, Vol. 31 No. 10, pp. 508–529. http://doi.org/10.1080/09544828.2020.1836611.
Kopec, D., Kabir, M.H., Reinharth, D., Rothschild, O. and Castiglione, J.A. (2003), “Human Errors in Medical Practice: Systematic Classification and Reduction with Automated Information Systems”, Journal of Medical Systems, Vol. 27 No. 4, pp. 297–313. http://doi.org/10.1023/A:1023796918654.
Michie, S., Atkins, L. and West, R. (2014), The Behaviour Change Wheel: A Guide to Designing Interventions, Silverback Publishing, London.
Norman, D.A. (1981), “Categorization of Action Slips”, Psychological Review, Vol. 88 No. 1, pp. 1–15. http://doi.org/10.1037/0033-295X.88.1.1.
Phua, D.H., Fams, E. and Tan, N.C. (2013), “Cognitive Aspect of Diagnostic Errors”, Ann Acad Med Singapore, Vol. 42 No. 1, pp. 33–41.
Pilnick, A., Hindmarsh, J. and Gill, V.T. (2009), “Beyond ‘doctor and patient’: Developments in the study of healthcare interactions”, Sociology of Health and Illness, Vol. 31 No. 6, pp. 787–802. http://doi.org/10.1111/j.1467-9566.2009.01194.x.
Rasmussen, J. (1982), “Human errors. A taxonomy for describing human malfunction in industrial installations”, Journal of Occupational Accidents, Vol. 4 No. 2–4, pp. 311–333. http://doi.org/10.1016/0376-6349(82)90041-4.
Rasmussen, J. (1983), “Skills, Rules, and Knowledge; Signals, Signs, and Symbols, and Other Distinctions in Human Performance Models”, IEEE Transactions on Systems, Man and Cybernetics, Vol. 13 No. 3, pp. 257–266. http://doi.org/10.1109/tsmc.1983.6313160.
Reason, J. (1990), Human Error, Cambridge University Press, Cambridge.
Reason, J. (2000), “Human error: Models and management”, British Medical Journal, Vol. 320 No. 7237, pp. 768–770. http://doi.org/10.1136/bmj.320.7237.768.
Rothschild, J.M., Landrigan, C.P., Cronin, J.W., Kaushal, R., Lockley, S.W., Burdick, E., Stone, P.H., et al. (2005), “The Critical Care Safety Study: The incidence and nature of adverse events and serious medical errors in intensive care”, Critical Care Medicine, Vol. 33 No. 8, pp. 1694–1700. http://doi.org/10.1097/01.ccm.0000171609.91035.bd.
Schattner, A. (2021), “Diagnostic errors: Under-appreciated, under-reported and under-researched”, International Journal of Clinical Practice, Vol. 75 No. 12. http://doi.org/10.1111/ijcp.14913.
Schwartz, A. and Elstein, A. (2008), “Clinical Reasoning in Medicine”, in Higgs, J., Jones, M., Loftus, S. and Christensen, N. (Eds.), Clinical Reasoning in the Health Profession, 3rd ed., Butterworth Heinemann, Woburn, Massachusetts, pp. 223–234.
Simon, H.A. (1972), “Theories of Bounded Rationality”, in McGuire, C.B. and Radner, R. (Eds.), Decision and Organization, North-Holland Publishing Company, Amsterdam, pp. 161–176.
Simon, H.A. and Newell, A. (1958), “Heuristic Problem Solving: The Next Advance in Operations Research”, Operations Research, Vol. 6 No. 1, pp. 1–10. http://doi.org/10.1287%2Fopre.6.1.1.
Snyder, H. (2019), “Literature review as a research methodology: An overview and guidelines”, Journal of Business Research, Vol. 104, pp. 333–339. http://doi.org/10.1016/j.jbusres.2019.07.039.
Stanovich, K.E. (2009), “Distinguishing the reflective, algorithmic, and autonomous minds: Is it time for a tri-process theory?”, in Evan J, St.B.T. and Frankish K. (Eds.), In Two Minds: Dual Processes and Beyond, Oxford University Press, New York, pp. 55–88. http://doi.org/10.1093/acprof:oso/9780199230167.003.0003.
Stanovich, K.E. (2018), “Miserliness in human cognition: the interaction of detection, override and mindware”, Thinking and Reasoning, Vol. 24 No. 4, pp. 423–444. http://doi.org/10.1080/13546783.2018.1459314.
Stanovich, K.E. and Toplak, M.E. (2012), “Defining features versus incidental correlates of Type 1 and Type 2 processing”, Mind and Society, Vol. 11 No. 1, pp. 3–13. http://doi.org/10.1007/s11299-011-0093-6.
Stanovich, K.E. and West, R.F. (2008), “On the Relative Independence of Thinking Biases and Cognitive Ability”, Journal of Personality and Social Psychology, Vol. 94 No. 4, pp. 672–695. http://doi.org/10.1037/0022-3514.94.4.672.
Tversky, A. and Kahneman, D. (1974), “Judgment under Uncertainty: Heuristics and Biases”, Science, Vol. 185 No. 4157, pp. 1124–1131. http://doi.org/10.1126/science.185.4157.1124.
Wears, R.L. (2009), “What makes diagnosis hard?”, Advances in Health Sciences Education, Vol. 14 No. 1, pp. 19–25. http://doi.org/10.1007/s10459-009-9181-3.
West, R. and Michie, S. (2020), “A brief introduction to the COM-B Model of behaviour and the PRIME Theory of motivation”, Qeios, Vol. 1, Available at: http://www.qeios.com/ (accessed 17 April 2023) http://doi.org/10.32388/WW04E6.