Introduction

Diagnosis and Error

"Problems in diagnosis have... been heavily dominated by physicians with little input from the cognitive sciences. What is missing... is foundational work aimed at understanding how clinicians in actual situations take a complex, tangled stream of phenomena... to create an understanding of them as a problem." (Wears, 2014)

Imagine a group of doctors within a hospital's intensive/critical care unit. They are engaged in a collective discussion about a particular patient. The patient has presented with a series of symptoms, including dizziness, breathing difficulties and eventual chest pain. She has been placed under continuous monitoring of her 'vital signs', including heart rate, body temperature, blood pressure, blood oxygen saturation and respiration rate. There has been a slow decrease in her blood pressure and blood oxygen saturation. The doctors are deciding what is the most likely cause of this patient's symptoms and how this may inform her future care/treatment. It is possible that the patient is suffering from pulmonary oedema, whereby fluid is collected in the air sacs of the lungs, causing severe and sometimes fatal congestion. The symptoms could also be suggestive of a tension pneumothorax, when a lung collapses. Alternatively, there could be a cardiac cause of the patient's condition. The doctors must integrate the information they have so far, align their individual mental models of the patient and decide the following:

1. Do they have enough information to diagnose the patient's condition?
2. If not, what extra information do they need? Are there further tests that need to be performed?

3. What actions should they start taking to treat the patient given the most likely diagnosis?

One of the difficulties within this scenario is that symptoms may be indicative of multiple underlying conditions. This example is illustrative of why many medical decisions are 'ill-structured' problems: they present several possible courses of action, and produce disagreements over both the current hypothesis for the patient's condition and desired end goal for that patient's care (Jonassen, 1997). Medical staff involved in a patient case can independently formulate very different understandings of a patient's condition and how it would be best to proceed. They have to then align their thoughts in order to align their actions as a cohesive team.

Diagnosis is a core aspect of several medical subdisciplines and is important for a number of reasons. Firstly, accurate diagnosis is crucial to a patient's treatment. Secondly, from a psychological standpoint, it allows for an extension of previous research on information gathering and confidence to an ecologically valid, real-world setting. Finally, past work looking at diagnosis has not yet provided clarity on the causes of diagnostic errors.

Accurate medical diagnosis is crucial to safe, high quality patient care and is a core part of a doctor's job. Research on diagnosis has been grounded in the incidence of errors. A report from the US Institute of Medicine (McGlynn, McDonald & Cassel, 2015) concluded that most patients will experience a diagnostic error within their lifetime. When looking at records of new diagnoses for spinal epidural abscess in the US Department of Veteran Affairs, Bhise et al. (2017) found that up to 55.5% of patients experienced diagnostic error. The Quality in Australian Health Care Study found that 20% of adverse events were due to delayed diagnosis (Wilson et al., 1999). Around 32% of clinical errors have been found to be caused by clinician assessment, particularly the clinician's failure to weigh up competing diagnoses (Schiff et al., 2009). Even using the most conservative of these estimates, the scale of

the diagnostic error is substantial when extrapolated to the population of patients. Diagnostic errors have also been found to lead to longer hospital stays and even increased patient mortality (Hautz et al., 2019). In addition to stays in hospital, errors also manifest in differences to treatment for patients. Unnecessary treatment (or 'overtreatment') was estimated to cost the US healthcare system 158-226 billion dollars in 2011 (Berwick & Hackbarth, 2012).

Diagnostic error is by no means the sole cause of medical incidents. There are a number of factors tied to the wider work environment, culture and technology that can contribute to incidents and errors. A lot of these factors are challenging to isolate and emulate in an experimental setting. By understanding the individual psychological factors of the diagnostic process however, we better understand how sociotechnical and environmental factors interact with and amplify individual contributors to diagnostic error. Gaining a greater understanding of the causes of diagnostic error can have important implications for future interventions within healthcare settings.

Cognitive Biases and Overconfidence in Diagnoses

Diagnostic error can stem from cognitive biases during the diagnostic decision making process, such as primacy (Frotvedt et al., 2020) or recency (Chapman, Bergus & Elstein, 1996) biases. While it seems intuitive that classical decision making biases affect those in healthcare too (Restrepo et al., 2020), the empirical evidence of impact for medical decision making is scant, (van den Berge & Mamede, 2013). One example from dermatology looked found examples of satisficing bias (premature closure) and anchoring were found, but few examples of others such as availability and representative biases (Crowley et al., 2012). One type of bias that has manifested in more experimental findings is overconfidence (Berner & Graber, 2008, Meyer et al.., 2013).

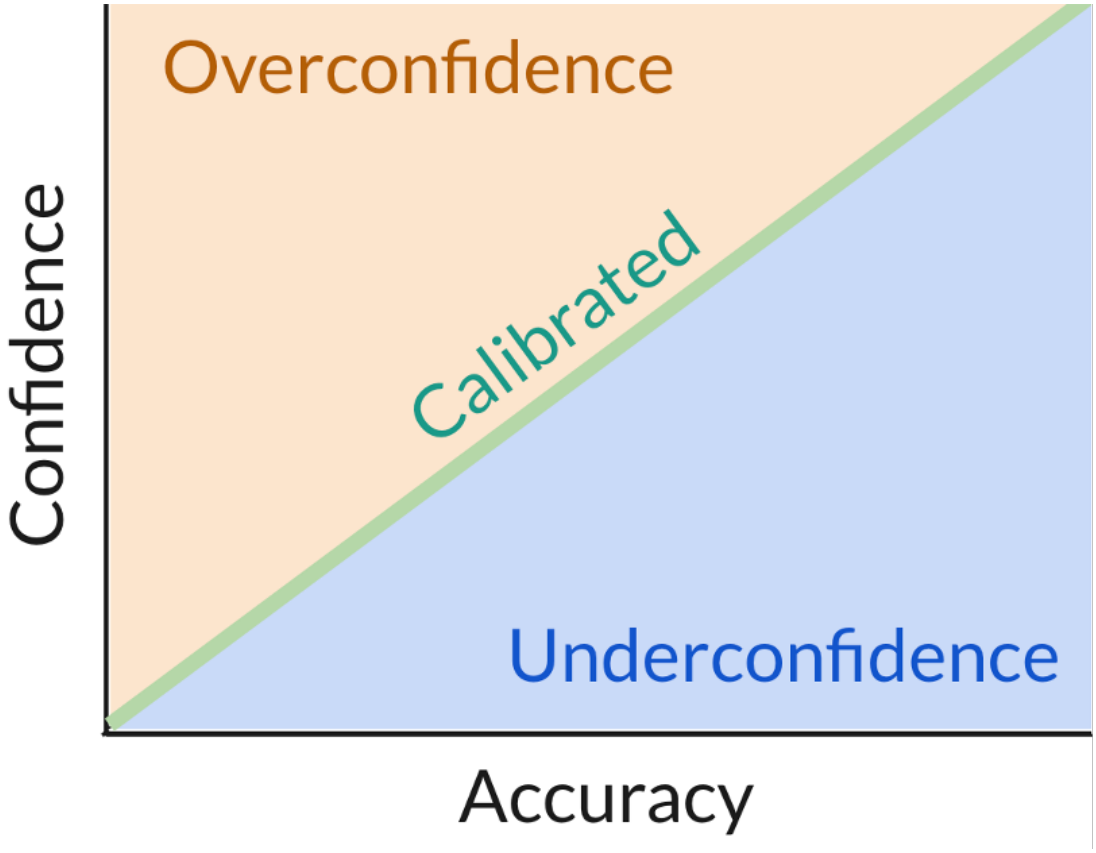
At this point, we shall revisit the scenario presented at the start of this section. In summary, a patient is presenting with a set of symptoms, requiring doctors to assign a diagnosis to guide future treatment. One of the doctors confidently presents their opinion that the patient has suffered a pneumothorax. The certainty with which the diagnosis is suggested makes it more difficult for others to disagree with, especially if the doctor is a consultant/attending such that there is a disparity in seniority.

Confidence in Cognitive Psychology

Confidence is the subjective assessment of a decision's quality or accuracy (Fleming & Daw, 2017). Confident individuals tend to be more influential on others in a group (Zarnoth & Sniezek, 1997) and can even causally increase the confidence of other observers (Cheng et al., 2021). This behaviour has been observed in mock jury trials, during which participants hear eyewitness testimonies presented with high confidence and then perceive those testimonies as more credible than testimonies provided with low confidence (Cutler, Penrod & Dexter, 1989, Roediger, Wixted & DeSoto, 2012). Confidence is a commonly used predictor of another person's accuracy, especially when feedback is not readily available of an individual's true accuracy. Confidence also varies across individuals with what may be considered a 'subjective fingerprint' (Ais et al., 2016), and individuals may be systematically underconfident or overconfident. Confidence has been explained computationally as the difference in the strength of evidence for a decision alternative compared to other alternatives (Vickers & Packer, 1982). After a decision is made, we continue to process evidence, i.e. we continue to think about a decision after it has been made and having 'second thoughts' or changes of mind are more likely with a lower level of confidence (Resulaj et al., 2009).

We refer to confidence as being 'calibrated' if it closely predicts objective accuracy (i.e., such that the individual is neither overconfident nor underconfident). In experimental studies, confidence sometimes exhibits impressive calibration to objective accuracy (Boldt & Yeung, 2015), which is thought to reflect people's ability

to evaluate the quality of evidence on which they base their decisions (Shekhar & Rahnev, 2023). But calibration is rarely perfect because confidence also depends on factors that do not directly correlate with accuracy, such as the time spent deliberating and the total amount of evidence considered (independent of the quality or consistency of this evidence) (Kiani, Corthell & Shadlen, 2014, Ko et al., 2022), as well as the mood (Rouault et al., 2018), personality (Schaefer et al, 2004), gender (Syzmanowicz & Furnham, 2011) and status (See et al., 2011) of the decision maker. The resulting under- and overconfidence matters: overconfident decision makers leap to premature conclusions and ignore useful information or advice, while underconfident decision makers waste time collecting evidence that will not improve their decisions (Desender, Boldt & Yeung, 2018). Effective decision making in groups likewise depends on team members sharing calibrated information about their uncertainty: Confident team members tend to be listened to more, which can lead others astray if they are overconfident (Zarnoth & Sniezek, 1997). Conversely, underconfident team members may be ignored or may fail to share potentially useful information (Silver, Mellers & Tetlock, 2021).



These features of confidence highlight its potential importance in healthcare, as overconfidence can lead to insufficient consideration of diagnostic alternatives and inadequate care (Kovacs, Lagarde & Cairns, 2020). In the absence of objective feedback, confidence can be used as a marker of how likely someone is to be correct (Price & Stone, 2004). In medicine, a lack of clearly communicated feedback can cause clinicians to proceed as if they have received positive feedback. This means that they may not adequately update their internal model of the patient and then increase their confidence inappropriately, whether working individually or in teams (Jaspen et al, 2022).

In a task that involved diagnosing ultrasound scans, it was found that overconfidence was inversely associated with the amount of clinical experience that the clinicians/participants had (Schoenherr, Waechter & Millington, 2018). However, it has also been found that underconfidence can be more prevalent than overconfidence, especially when comparing medical students to residents (Friedman et al., 2005).

Similarly, Yang and Thompson (2010) found that experienced nurses exhibited similar performance to nursing students, but were more confident in their judgements, showing differences in confidence calibration across experience levels. More broadly, highly confident members within a group could unknowingly reduce the chance of less confident members speaking up about potential errors, which is a common problem within healthcare (Hémon et al., 2020). Overconfidence has also been linked to a lower likelihood of sufficient patient management and clinical effort as per a field study in Senegal (Kovacs, Lagarde & Cairns, 2019).

We would argue that building on the current research landscape of diagnostic confidence is important. If there is an assumption that others will calibrate their confidence to their true accuracy, this would mean that heeding high confidence advice or judgements would be an optimal strategy for maximising accuracy. However, this can be a serious issue when high confidence errors lead others astray. This is important, as in addition to seniority and speciality experience, a clinician's confidence is one of the only markers available for other clinicians and for patients when making key medical decisions. One underexplored avenue in current research is the role that information seeking during the diagnostic process affects confidence.

Information Seeking and its link to Confidence

Clinicians generate hypotheses and then gather information to reduce the space of hypotheses. They should ideally eliminate hypotheses from consideration only when it makes sense given the incoming evidence. By the same token, they should also not continue attaching themselves to a hypothesis when there is overwhelming evidence to the contrary. One conclusion of Wason (1960) was that individuals struggle to remove a hypothesis from consideration even if they receive evidence against it. Understanding how individuals generally reason about a possible space of hypotheses is interesting for understanding how the reasoning process works differentially for novices and experts, especially in a specialised domain

such as medicine. One question that is worth investigating is how the 'process of elimination' affects confidence.

The link between confidence and information seeking has been previously investigated in cognitive psychology research. Information can be gathered that is either in support of or against an individual's beliefs or decisions, with information being used to accumulate strength of evidence in favour of different decision alternatives (Vickers & Packer, 1982). Desender, Boldt & Yeung (2018) found that higher variability was associated with lower confidence and higher information seeking. However, the mere quantity of information, even if that information favours the non-preferred option, may increase confidence in of itself (Ko, Feuerriegel, et al., 2022).

There is also evidence to assume that information seeking is important within medical diagnoses too. Notably, Gruppen, Wolf & Billi (1991) found that clinicians were less confident when they had to seek relevant information for themselves compared to all information was already provided, indicating that information seeking as a task is contributory to formulating diagnostic confidence. While this shows the relationship in one direction, past work has also viewed confidence as contributory to further information seeking. Pathologists with more calibrated confidence were found to request more information, such as second opinions or ancillary tests, when unconfident in their judgements (Clayton et al., 2022). In a sample of 118 physicians presented with patient vignettes, it was found that higher confidence was associated with a decreased amount of diagnostic tests being ordered, even if confidence and accuracy were larger decoupled/miscalibrated (Meyer et al., 2013). It has also been observed previously that physicians may 'distort' neutral or inconclusive evidence to be interpreted as supporting prior beliefs (Kostopolou et al., 2012). Similarly, it has been found that a patient's case history that suggests a particular diagnosis prompts selective interpretation of clinical features that favour the initial diagnosis (Leblanc, Brooks & Norman, 2002). Together, these findings have implications for how clinicians may seek and integrate evidence when making decisions and how patterns of receiving information could affect decision confidence and in turn confidence calibration.

Diagnostic decisions have been thought of as 'ideal' when using the hypothetico-deductive process (Kuipers & Kassirer, 1984), whereby hypotheses are formulated based on specific features of a patient and are then linked to established criteria for a diagnosis, with further information gathering to test these hypotheses (Higgs et al., 2008) or eliminate others. This account was challenged by Coderre et al. (2003), who found that diagnosis can based more on pattern recognition, especially for more experienced clinicians. Either way, the bridge between confidence and information seeking is the reasoning strategy utilised by clinicians. Diagnostic reasoning is currently taught using cognitive frameworks such as the surgical sieve and the ABCDE pneumonic. However, current education does not account for differences in reasoning strategies, whether strategies may meaningful vary by case and by clinician and how these strategies have a downstream influence on the diagnostic process in terms of seeking information, generating differentials and formulating confidence.

Research Questions

There is a need for the teaching and assessment of non-technical skills and human factors in healthcare (Higham et al., 2019), which is currently not addressed in a widespread standardised manner in speciality curricula (Grieg, Higham & Vaux, 2015). Curricula within medicine also place little emphasis on how uncertainty is communicated and approached in medical decision making (Hall, 2002). In addition, there is little work that informs how information seeking is taught within medical reasoning other the use of cognitive frameworks (such as the 'surgical sieve') and pneumonics (such as Airway, Breathing, Circulation, Disability, Exposure). Clinical experience may also be connected to risk aversion and further information seeking behaviour (Lawton et al., 2019), which offers an important avenue for future medical education. Hence, this research informs medical education of non-technical skills such as diagnostic reasoning, especially around evaluating diagnostic differentials and seeking information during the diagnosis process.

Thesis Structure

The following sections are structured as follows. Firstly, we will present a scoping review of the medical and psychological literature in which confidence or certainty has been studied within diagnostic studies. This review will map out the broad findings from this extant literature and identify gaps in our current understanding, some of which this DPhil aims to fill. Next, I will present an online behavioural study with medical students where participants freely sought information and provided diagnostic differentials at different stages during a series of patient vignettes. This study allows us to study how diagnostic differentials and confidence are affected by patterns of information seeking. The following section then details an in-person using a similar paradigm where medical think aloud as they are making these diagnoses, with the aim to use these think aloud utterances to classify different diagnostic reasoning strategies. These different strategies can be used to reanalyse the online study to investigate how reasoning strategies affect confidence and information seeking. The third empirical study seeks to look at diagnostic decisions in a more naturalistic manner by using virtual scenario paediatric scenarios to investigate differences in information seeking and confidence. Finally, I present a reflective chapter based on observations in Intensive Care, whereby the findings from this DPhil are contextualised within the decisions made during actual medical practice.