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REFLECTIONS

Mental workload as a key factor in clinical decision making

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Abstract The decision making process is central to the practice of a clinician and has traditionally been described in terms of the hypothetico-deductive model. More recently, models adapted from cognitive psychology, such as the dual process and script theories have proved useful in explaining patterns of practice not consistent with purely cognitive based practice. The purpose of this paper is to introduce the concept of mental workload as a key determinant of the type of cognitive processing used by clinicians. Published research appears to be consistent with 'schemata' based cognition as the principle mode of working for those engaged in complex tasks under time pressure. Although conscious processing of factual data is also used, it may be the primary mode of cognition only in situations where time pressure is not a factor. Further research on the decision making process should be based on outcomes which are not dependant on conscious recall of past actions or events and include a measure of mental workload. This further appears to support the concept of the patient, within the clinical environment, as the most effective learning resource.

Keywords Cognitive psychology · Decision making · Education · Mental workload · Schemata

Introduction

The process by which clinicians perceive and draw conclusions from clinical data is important for educators in that we can only select appropriate teaching and assessment methods once the underlying cognitive constructs have been clearly defined.

Traditionally, clinical reasoning has been understood as a cognitive, deductive process, involving the processing of large amounts of information and the inference from them of logical conclusions (Mylopoulos and Regehr 2007). It has been recently described;

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> It often entails careful observation, appropriate elicitation of historical information, accurate performance of physical maneuvers, the generation of hypotheses, appreciation of the relationship between each piece of data and each hypothesis, and attempting to confirm/disconfirm hypotheses through the appropriate ordering of diagnostic tests. (Eva 2005)

However, the same author describes a second 'non-analytical' form of reasoning, which is also used in clinical practice, but cautions that "excessive reliance on non-analytic approaches to clinical reasoning can be a source of diagnostic error" (Eva 2005). For the following discussion, it is important that the activity of the clinician is not seen as a pure cognitive process, but one which includes physical activity. It is also seen as 'expertise', requiring years of sustained, deliberate practice (Ericsson 2007) and one which can generate provisional diagnoses even before any verbal exchange has occurred (Epstein and Hundert 2002), rather than a skill which can be taught.

While a review of the available evidence in medicine has concluded that "there is no such thing as clinical reasoning: there is no one best way through a problem" (Norman 2005), in other complex fields such as aviation, expertise is often described more simply as a progression through: (1) a cognitive phase, reliant on conscious deliberation on fact, (2) an associative phase where simple rules predominate and (3) an autonomous phase which "requires little cognitive resources as performance is nearly automatic, and attention can be directed to other tasks" (Webb et al. 2010). Interestingly, in a recent publication studying medical decision making, the same categorisation was applied, but with the reverse order of development and value placed on each category (Ghafouri et al. 2011), with pattern recognition described as the lowest form of clinical decision making.

Lessons from cognitive psychology

This paper describes a model of clinician decision making based on cognitive psychology and seeks to determine whether it is compatible with published evidence. It must first be recognised that the model presented is very simple and cannot be held as an accurate summary of the available literature, but rather a model designed to aid understanding and guide possible future research. The model is based on two principles of human cognition:

Firstly, while early work suggested that our working memory (Miller 1956) was only able to hold around seven individual pieces of information, this has more recently been challenged and the true figure may be as low as four (Cowan 2010; Warfield 1988). That is, we can only be mindful of around four pieces of information, without the next piece of information displacing the first.

Secondly, the ability of the human mind to process information, our 'mental capacity' is both finite and highly constrained. During many common tasks, the percentage of our mental capacity in use at a given time, or 'mental workload' can often come close to 100 % (Welford 1978). When this state of 'overload' occurs, information processing becomes inefficient, with consequent loss of information, leading to the risk of poor performance (Byrne et al. 2010). In recent times, this theoretical approach has been used to study the effect of telephone use while driving using simulator studies, leading to the conclusion that we do not possess the mental capacity to drive safely whilst also holding a telephone conversation (Cantin et al. 2009; Patten et al. 2004). The same methodology has been applied to a variety of clinical situations (Beard et al. 1994; Byrne et al. 1998, 2010; Gaba and Lee 1990; Stefanidis et al. 2007; Weinger et al. 1994; Yurko et al. 2010). It must be acknowledged at this point that mental workload is now widely conceived as multiple resources (Wickens 2008), but will be discussed here as a single resource to aid clarity.

It is immediately obvious that these two principles are contrary to our daily experience that humans are able to complete complex, challenging tasks. Research indicates that this is possible through the use of mental models or schemata (McVee et al. 2005), which overcome the problem of limited working memory because rather than seeing complex information as a collection of individual items, it is ‘chunked’ into schemata which can then be manipulated using less workload (Gobet 2005). However, schemata should not be seen as simple accumulations of fact, but instead as massively complex associations of sensations, ideas and actions which are now being linked to discrete neuroanatomical sites (Ruiter et al. 2010; Tse et al. 2007). This suggests that the ‘context’ is a key factor in learning (Albanese 2000) and, supported by experimental data, for example, that information learned underwater was recalled better underwater (Godden and Baddeley 1975). It would also suggest that any decontextualised assessment process, such as written exams or even Objective Structured Clinical Examinations (OSCEs) would fail to measure the schemata based learning required for effective clinical practice.

Schemata based practice

We consider that it is useful to simplify the concept of schemata based practice into four components:

Perceptual schemata used to convert the complex sensory input from the world around us into meaningful constructs. Therefore, rather than being a passive process, perception is the unconscious comparison of sensory input to previous experience. For example, a student listening to the heart, at first hears noise, then hears defined heart sounds and with time can hear murmurs. Therefore, perception is as dependant on the prior learning of the observer as it is on the sensory input. This is supported by the finding that many aspects of a situation, such as mannerisms or gait, appear to be processed entirely unconsciously (Young et al. 2007).

Abstract schemata internal representations of both external objects (car, patient, meningitis). For example, a student may recognise a systolic blood pressure of 60 mmHg as hypotension. With experience, the concept comes to be developed into one of ‘shock’ and hopefully into one linked to ‘emergency’ and ‘call for help’. Importantly, this also includes concepts such as ‘self’, ‘professionalism’ and ‘truth’, so that, for example, not immediately treating a systolic blood pressure could include concepts of ‘inadequate treatment’ or ‘malpractice’.

Motor schemata pre-programmed sequences of actions, such as walking or suturing, but also more complex sequences such as asking questions or performing routine examinations.

Metacognition conscious processing of information and the supervision of action. This represents our ability to consciously direct attention or to mindfully evaluate information. Thus, we can walk and think at the same time, as the walking is entirely schemata based. However, although we can consciously choose to place our feet and monitor the walking process, we cannot mindfully walk and think at the same time. Further, while our metacognitive capacity is small and fixed, our capacity to use schemata based cognition is extremely large. For example, a clinician observing a patient on a ward will have subconsciously identified many subtle signs and linked them to a range of abstract concepts before any social interaction has occurred. Even when such interaction occurs, the form of the interaction will depend on those prior concepts. For example, it is likely that on first encountering a patient, an experienced clinician would immediately recognise (unconsciously) signs of mental depression, link this to concepts of vulnerability, and then, just as unconsciously, adopt a more sensitive manner. In contrast, an inexperienced clinician may miss the subtle signs, fail to recognise the vulnerability and not have developed the ability to rapidly adapt their approach. In the example given, the inexperienced clinician is much less likely to successfully interact with the patient. The 'mind' of an expert is therefore represented in Fig. 1.

We would therefore agree with Eva that there are two distinct methods of reasoning; a conscious metacognitive method as well as a largely unconscious schemata based method. However, we would suggest that in all but the most inexperienced staff, it is the schemata based method which is normal in clinical practice and the metacognitive process which has a minor role in cases where time allows a slow and careful analysis of the available data. This is mirrored by a review (Alberdi et al. 2001) which concluded:

(a) experts perform better than novices not because they use superior skills, but because they possess superior domain knowledge (a richer repertoire of schemata)
(b) as a consequence, experts have a better representation of the domain than do novices; this allows them to focus on those aspects of the task which are more relevant, and thus process information faster and more accurately
(c) experts' problem solving is opportunistic: they make better use than novices of whatever sources of information are available and relevant to the task, and search effectively for relevant missing information.

The place of mental workload in decision making is becoming more important now that established methods of measurement are being established in a range of fields (Beard et al.

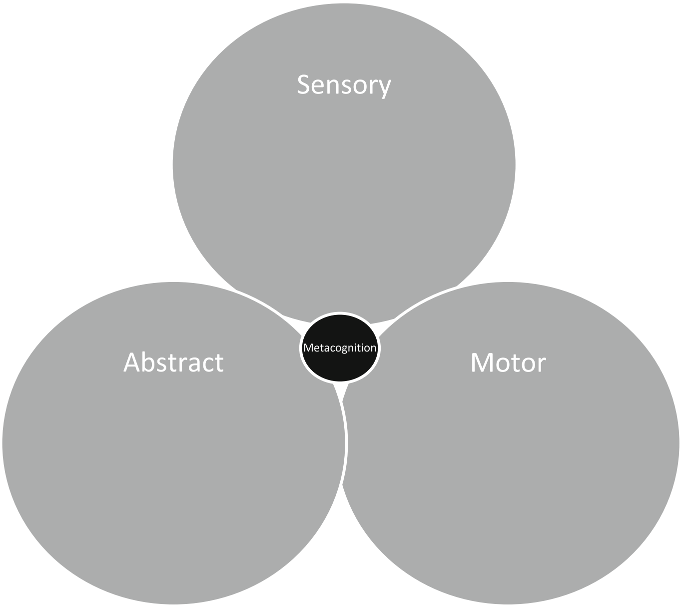

Fig. 1 Diagrammatic representation of mental schemata and metacogniton

1994; Bertram et al. 1990; Byrne et al. 2010; Carswell et al. 2005; Gaba and Lee 1990; Hertzum and Simonsen 2008).

Published evidence

The description above is very similar to that of the 'dual process theory' (Pelaccia et al. 2011) and 'script theory' (Charlin et al. 2007), however, both view the process as largely cognitive and they do not identify mental workload as the key to determining which mode is used in practice. The question is whether the above is consistent with published studies. The following are included as illustrations only.

In early research which involved either 'think aloud' or stimulated recall of clinical decision making (Norman 2005 ref 2–3) suggested a 'hypothetico-deductive' model where possible diagnoses were generated and then interpreted in the light of evidence. We would suggest that any description generated by an individual in retrospect, would be based on a metacognitive process and would therefore necessarily exclude any unconscious or schemata based decision making. This is supported by the finding that such studies did not demonstrate a difference between novices and experienced staff. Similarly, a study in an emergency department (Ghafouri et al. 2011) appeared to show that 'knowledge based' or metacognitive methods were used in 100 % of cases by senior staff with only less experienced staff using 'skill based' or schemata based diagnostic skills, was based on post event recall by staff asked to explain their diagnostic method. In a model of a highly time limited telephone consultation by trainee emergency practitioners, a pattern of very rapid decision making based on incomplete information was evident (Larsen and Risor 1997).

In a study (Patel and Groen 1986) using verbal reports of experienced and novices presented with written clinical scenarios, experts provided more accurate summaries, but used basic science knowledge less often than novices, suggesting that experts were able to recognise the correct solutions; and therefore had less need to use a knowledge based, metacognitive approach. This is supported by a study (Schmidt et al. 1988), where, when faced with much more complex problems, experts used basic science knowledge more often than novices. Thus, when faced with a difficult problem that was not amenable to schemata based methods and allowed unlimited time, metacognition could be used to find a solution. This is further supported by the finding that increasing the complexity of clinical cases resulted in increased processing time and an increase in the number of literal propositions recalled afterward (Mamede et al. 2007). This indicates that although experts use schemata in normal practice, it does not negate the fact that they also have better cognitive skills.

The demonstration of the 'primacy' effect (Cunnington et al. 1997), by which the final diagnosis is affected by the order in which information is presented, is also consistent in that as information is presented it is likely to activate schemata, which may then alter the interpretation of data which follows, although a recent study suggests that the interaction between prior experience and current decision may not always be simple (Mamede et al. 2010).

Of particular interest are studies which have included non-relevant information in prior material, such as the age and occupation of the patient in a case. We would anticipate that such information would be included in any schemata generated and would therefore affect later diagnostic decisions. This finding has been demonstrated experimentally (Norman et al. 2007; Sibbald et al. 2011). If clinicians are largely dependant of schemata, then the ability of any clinician will vary widely depending on prior experience and may depend on non-clinical factors such as the environment in which the material was learned/assessed.

While the above have centred on the diagnostic abilities of clinicians, other studies have shown (Schmidt and Rikers 2007) that the provision of prior information affected the ethical decision making process as well (Sah and Loewenstein 2010).

Implications for educators

If mental workload an important factor in cognition, then there are important implications for educational design, as has already be suggested (Ruiter et al. 2010; Van Merriënboer and Sweller 2010), with early clinical exposure a key recommendation. However, we would suggest that a key consideration is the mental workload of the subject. Students are not only engaged in learning from clinical material, but are also often engaged in practical tasks, either in the form of physical tasks, such as examination or verbal tasks such as communication. Under these conditions, the mental workload associated with the clinical task may interfere with both the perception and processing of information. Research during clinical practice has show that unexpected problems may significantly reduce the perception of new stimuli (Byrne et al. 2010) and that vigilance is impaired during the learning process in a surgical simulator (Stefanidis et al. 2007). The suggestion from this research is that it may be difficult or impossible for students to be aware of their own performance until their mental workload has reduced below their capacity or in other words that a degree of autonomaticity has developed. This strongly supports the concept of integrated learning with practice and theory developed throughout a student's career.

An important distinction at this point must be that we are not advocating that clinical practice should become automatic and unthinking. The importance of learning basic science is not diminished, but understood as a method of supporting the development of more effective schemata (Woods 2007). The suggestion is that until a clinician is able to perform the required tasks in a largely automated way then they will not have any spare capacity to monitor their own performance or to learn, in the same way that a pianist cannot play music until the mechanical process of hitting the right key has become largely automated. Clinicians are often faced with a wealth of diagnostic information in a situation where they are required to respond rapidly, often at the same time as completing other tasks such as keeping notes or filling in forms. Education needs to prepare students to deal with this reality.

We do recognise that, we must also guard against 'Neuromyths' (Ruiter et al. 2010) where over reliance on simplified psychological theories can lead to damaging interactions between neuroscience and education. In particular the simplicity of this model makes it compatible with a range of experimental data and therefore difficult to disprove. It must be recognised that the examples cited previously are only a very small proportion of a large literature and that the only valid test of schemata theory is whether it allows us to design and implement more effective teaching programmes (Charness and Tuffiash 2008).

Conclusions

Some published evidence supports that the concept that we can describe the clinical decision making process to a combination of two cognitive domains of schemata based, pattern recognition and a metacognitive, logical one. The main method used by a clinician is likely to be determined by two factors—the complexity of the information presented and their concurrent mental workload (principally, time pressure). Therefore, when presented with a limited volume of decontextualised information, metacognition is likely to predominate. In contrast, during the complexity and time pressure of clinical practice, schemata based methods are routinely used.

In order to determine whether this approach is valid, we need to re-evaluate the clinical diagnostic approach by attempting to study it during realistic clinical or simulated situations. In addition, we need to develop a method of defining the complexity of the information presented (the context), the mental workload of the subject and a method of probing diagnostic processing that does not depend on metacognition based recall of past events. While other disciplines and professions may provide guidance and methodology, this process seems likely to prove challenging.

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