

## Clinical reasoning and pain

M. Jones

*School of Physiotherapy, University of South Australia, Adelaide, Australia*

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**SUMMARY.** Clinical reasoning is reviewed with respect to the historical and continuing need for critical inquiry skills, the hypothetico-deductive basis of sound reasoning, factors influencing therapists' reasoning, and ways of promoting critical yet creative reasoning. The importance of clinicians' organisation of biomedical and clinical knowledge and the inclusion of the patient in the problem solving and decision making processes are emphasised.

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### THE NEED FOR CLINICAL REASONING

It is interesting to reflect on misdirections that have occurred throughout the history of science, largely due to a lack of critical and open inquiry, two essential elements of clinical reasoning. A somewhat dramatic example is evident in the misconceptions which surrounded the role of the heart and arteries in the days of Aristotle (Bergland 1985). Influenced by the teaching of Pythagoras and Plato and by his own animal dissections, Aristotle believed that the substance of life, which he labelled 'quintessence', was carried from the heavens into the human body through the trachea to the lungs and then on to the heart. The hollow arteries of the body were believed to carry this quintessence or life force to all other organs of the body. These conclusions led Aristotle to assign the function of intelligent thought to the heart, not the brain. This belief that the heart was the home of the highest soul and the organ of rational thought was to persist for centuries. It was nearly 2000 years before Aristotle's belief in the importance of quintessence was challenged by William Harvey through the publication of his book on the circulation of blood.

How can misbeliefs seemingly as large as this be perpetuated for so long? Could science and its associated disciplines, such as medicine or physiotherapy, be misdirected to this extent in modern times? Richard Bergland (1985), in his book *The Fabric of Mind*, sug-

gests they can and are, and Bergland provides the example of the commonly accepted notion that electricity is the stuff of thought, a misconception that has existed for 200 years.

The power of any paradigm that dominates a discipline is enormous. Research and treatment practices will be directed by the prevailing paradigm and if it is in error, the advancement of science and in turn health care can be misdirected. Bergland (1985) demonstrates convincingly how this has occurred in modern neurology and goes on to explain how the current understanding that the brain is a gland, a view which is still relatively new, is changing the understanding of brain illness and its associated treatment.

As a profession, with its clinical theories being based on a combination of scientific rationale and quasi-empirical approaches, physiotherapy is also vulnerable to misdirection. A principal fault behind many of the colossal misdirections through the history of science has been the blind acceptance of what is written or professed as truth at the time. Historically, questioning the accepted theory of the day was risky practice, as in the case of Michael Servetus who pronounced in 1553 that blood, like the stars, could also move by circulation. For this controversial statement Servetus was burned at the stake (Bergland 1985). Open mindedness, the questioning of existing beliefs, and reflective thinking are essential to avoid misdirection. Fortunately these traits are less stringently punished in more recent times, although contradicting the prevailing view today still runs the risk of ridicule and isolation, and attitudes and hierarchies continue to exist which inhibit open inquiry.

Physiotherapy has come under criticism in recent years for its attempt to extrapolate pain science to clinical practice without validation. But should clinicians

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**Mark Jones BS(Psych), PT, MAppSc (Manipulative Physiotherapy)**, School of Physiotherapy, Faculty of Health and Biomedical Sciences, University of South Australia, North Terrace, Adelaide, South Australia 5000.

Correspondence and requests for offprints to MJ.

and patients wait for theory and practice to be validated? Thomas Kuhn (1962), a historian of science, describes in his book *The Structure of Scientific Revolutions*, how significant shifts in the paradigms or philosophies of science have not generally occurred because of carefully planned scientific development. Rather, breakthroughs or new directions have most frequently come about from the explorations and ideas of lone individuals, often sparked by accidental or chance observations or quite unscientific moments of personal insight.

Clearly a balance is needed. Clinical ideas must be encouraged and shared but not accepted as fact. Clinicians must continually attempt to relate clinical practice to the pain sciences while at the same time not be constrained to practice within the borders of only what is known. Clinical ideas should in turn guide research.

Clinical reasoning provides a safeguard against the risk of having the popular theory and clinical techniques of the day adopted without question and hence thwarting alternative theories and clinical practice. Clinical reasoning is the thinking underlying clinical practice. It is the foundation of professional clinical practice. Without sound clinical reasoning, clinical practice becomes a technical operation requiring direction from a decision maker (Higgs & Jones 1995). The importance of skilled clinical reasoning should be evident, not only to avoid prolonged misdirection in beliefs, but particularly – given the enormous and expanding body of information which exists in the pain sciences – to explain the pain experience, and physiotherapy's relatively late attempt to incorporate that knowledge into its existing theories and clinical practice in pain management.

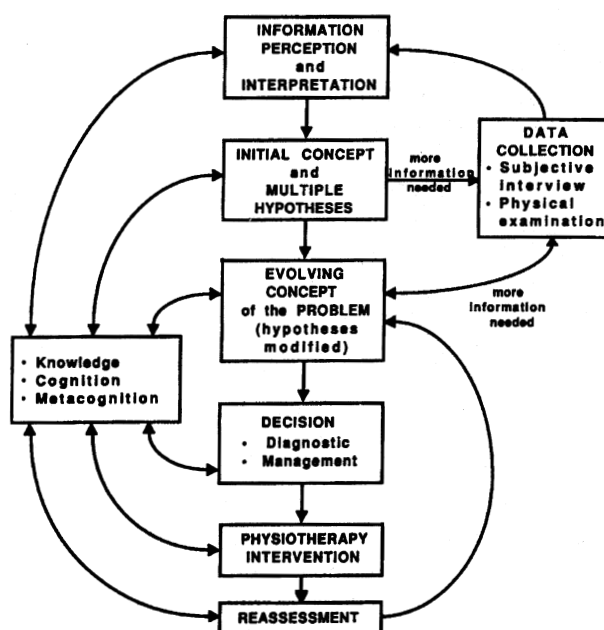


Fig. 1—The clinical reasoning process (adapted from Barrows & Tamblyn (1980)).

While clinical reasoning is conceptually very simple, effective clinical reasoning in practice can be extremely difficult and is fraught with errors.

### The clinical reasoning process

This simple diagram (Fig. 1) is used to portray a process of clinical reasoning used in pain management. In all clinical settings, the clinician's reasoning begins with the initial data/cues obtained. For example, in a rehabilitation setting this may be a referral, case notes, observation of the patient in the waiting room as well as opening introductions and inquiries with the patient. This preliminary information will elicit a range of impressions or working interpretations. While typically not thought of as such, these can be considered hypotheses. The cognition involved in hypothesis generation includes a combination of specific data interpretations or inductions and the synthesis of multiple clues or deductions. In most settings the initial hypotheses will be quite broad, such as 'appears to be a back or hip problem'. Initial hypotheses may be physical, psychological or socially related with or without a 'diagnostic' implication.

All clinicians have an element of routine to their examination. Individual clinicians will have identified, through experience, the categories of information which they have found to be particularly useful for problem identification and management decisions (e.g. site, behaviour and history of symptoms; family and social information; psychological profile, functional and structure specific tests of cognition, perception, and the neuro-musculo-skeletal system; ergonomic and environmental analysis, etc.). While a degree of routine commonly exists, the specific inquiries and tests should be tailored to each patient's unique presentation. Initial hypotheses will lead to certain inquiries and tests specific to that patient. This cognitive activity of hypothesis testing would ideally include the search for both supporting and negating evidence. The resulting data are then interpreted for their fit with previously obtained data and hypotheses considered. Even routine inquiries, tests and spontaneous information offered by the patient will be interpreted in the context of initial hypotheses. This hypothesis generation and testing process continues until sufficient information is obtained to make a diagnostic decision (i.e. identification of the source, mechanisms and underlying cause of the patient's impairments) and a management decision. The clinical reasoning process continues throughout the ongoing-management. In particular, clinical intervention serves as another test of hypotheses. Re-assessment may provide support for existing hypotheses and chosen course of action, or elicit the formation of new hypotheses or perhaps signal the need for further data collection and problem clarification (e.g. additional examination or referral for other specialist consultation). At the micro level clinicians are constantly reading patient responses

and making in-treatment clinical decisions to modify and improvise their actions. At a macro level whole treatment sessions or even multiple treatments will be used to test various hypotheses.

The clinical reasoning process portrayed here should be seen as a combination of pattern recognition and hypothesis testing. Pattern recognition is based on the notion that the storage of knowledge in memory occurs in the form of 'schemata'. They are prototypes in memory of frequently experienced situations that individuals use to recognise and interpret other situations (Rumelhart & Ortony 1977). A clinical pattern or schema stored in memory would include not only the symptoms, context of those symptoms, and signs but also the associated 'if ... then ...' production rules which guide our action. Production rules state that if certain features or conditions are present, then certain diagnoses or management plans are recalled.

This process of pattern recognition, where problem cues elicit recognition of the solution without any specific hypothesis testing has been labelled inductive or forward reasoning. Considerable evidence exists to suggest this is the reasoning process used by expert clinicians when confronted with familiar problems (Groen & Patel 1985; 1990; Ridderikhoff 1991). Forward reasoning is efficient, fast and dependent on a good knowledge base in the particular area of practice (Arocha et al 1993). On the other hand, when confronted with unfamiliar problems, experts, like novices, are forced to test their hypotheses in what is called backward reasoning. In backward reasoning, hypotheses elicit a return to the data for either re-interpretation or the collection of further confirming or negating evidence (Patel & Groen 1991). Clearly when attempting to understand the complex interaction of factors which contribute to an individual's pain experience, clinicians must continually engage in backward reasoning. In fact in those situations where pure forward reasoning or simple pattern recognition has dominated, the result is often an unfortunate, unfair, and naive classification of a patient's pain experience into a single structural diagnosis.

### **Factors influencing clinical reasoning**

Clinical reasoning is influenced by a mixture of external and internal factors which relate to the specific task, the setting, the patient, and the decision maker. External factors include the client – his or her needs, expectations, values and beliefs; professional and institutional canon; community needs and expectations; resource availability and funding. Internal factors include personal values and beliefs; general and domain specific knowledge and individual cognitive or reasoning strategies. Critical factors pertaining to the decision maker, including the clinician's knowledge base and his or her cognitive and metacognitive skills are discussed further. for a more detailed discussion of other factors influenc-

ing clinical reasoning the reader is referred to May and Dennis (1995).

### *Cognition*

Cognition refers to thinking processes such as data analysis and synthesis and inquiry strategies such as hypothesis testing (Carr et al 1995). While clinical expertise has been linked more to the clinician's organisation of knowledge than the process of clinical reasoning used, cognitive skills and knowledge are interdependent. For example, the inquiry strategy of hypothesis testing, including confirming and disconfirming strategies, plays a significant role in the acquisition of knowledge (Lawson et al 1991).

Errors in clinical reasoning are frequently related to errors in cognition. Examples of these include overemphasis on findings which support an existing hypothesis, misinterpreting non-contributory information as confirming an existing hypothesis, ignoring findings which did not support a favoured hypothesis, and incorrect interpretations related to inappropriately applied inductive and deductive logic (Elstein et al 1978; Ramsden 1985; Jones 1992). However, many clinicians will be unaware of the thinking processes they use when examining and treating a patient and hence errors may well go unnoticed.

The most common error is an over focus on one's favourite hypothesis. This of course is an inherent limitation of pattern recognition – that is when you try to put things in to discrete boxes, the boxes themselves become the focus of your attention and it is difficult to see any patterns outside those boxes. Care is needed to avoid a preoccupation with one diagnosis, one structure or one system at the expense of the others as this will be reflected in the management. That is: if all you have is a hammer, everything looks like a nail.

### *Metacognition*

Metacognition refers to clinicians' awareness and ability to think about their thinking. Most spontaneous actions that professionals take are not elicited by a rule or plan that was consciously in the mind before acting (Cervero 1988). That is, experienced clinicians are able to recognise and respond appropriately to relevant cues, even without explicit awareness of their own reasoning. This may be characterised as 'Knowing-in-action', a phrase coined by Donald Schon (1983; 1987). Clinicians, however, do not emerge from their formal education with this level of knowing. Expertise can only be reached through clinical experience where reasoning involves 'reflection-in-action' and 'reflection-about-action'. 'Reflection-in-action' refers to thinking about what you are doing while you do it. That is, as the clinician encounters a problem, he or she engages in a process of critical analysis that allows for self-correction or adaptation of practice. It is typically used in situations of uncertainty or when unexpected results are obtained. For example, in the midst of working through a difficult

problem clinicians may ask themselves 'What is the key problem here? What are the salient features? What are the most likely explanations? How could I test these further? etc.' This 'reflective conversation' with the situation involves on the spot experiments or what could also be called hypothesis generation and testing. Reflection-about-action is a similar process that occurs retrospectively as the clinician thinks back about what happened in practice. By promoting awareness, reflection and critical appraisal, the recognition of clinical patterns hidden in the ambiguity of the presentation or the acquisition of new patterns not previously appreciated can be realised and clinical outcomes can be better understood and improved upon.

### *Knowledge*

The third factor cited which significantly influences clinical reasoning is knowledge. A consistent finding in the clinical reasoning literature is that expertise and diagnostic accuracy are dependent on clinicians' knowledge in a particular area (Barrows et al 1982; Norman et al 1982; Patel & Groen 1986; 1991; Grant & Marsden 1987; 1988; Bordage et al 1990; Bordage & Lemieux 1991; Elstein et al 1990; Schmidt & Boshuizen 1993; Arocha et al 1993). Of importance is not simply the amount of knowledge, in the form of how many facts they might know, but more the organisation of their knowledge. With the recognition that knowledge is probably the most important variable influencing clinical reasoning, and realising that the body of knowledge pertaining to neuro-musculo-skeletal pathology and the associated pain mechanisms is more than any single clinician could hope to acquire, yet alone manage, physiotherapists must be critical of knowledge sought and keep in perspective what they need to know versus what is nice, marginal or irrelevant to know (Hislop 1985).

### *Biomedical knowledge versus clinical knowledge*

There are many ways in which types of knowledge have been classified, but for the purposes of this discussion the distinction between biomedical and clinical knowledge is used (Jones et al 1995). For a more thorough discussion of knowledge the reader is referred to Higgs and Titchen (1995). In the context of neuro-musculo-skeletal physiotherapy biomedical knowledge is used to refer to what is known or believed in the basic sciences particularly as it relates to anatomy, pathomechanics, pathophysiology, psychology, pain mechanisms and healing. Clinical knowledge on the other hand refers to knowledge such as clinical patterns and if:then guides to action which clinicians use on a day to day basis with or without a sound biomedical basis.

The role of biomedical knowledge in the clinical setting is debated. Some researchers have taken the stance that biomedical knowledge is not explicitly utilised by practising clinicians involved in diagnosing a familiar case (Patel & Groen 1986; Patel et al 1990; Patel & Kaufman 1995). Others maintain that with increasing

clinical experience biomedical knowledge becomes encapsulated in clinical knowledge (Boshuizen & Schmidt 1992; 1995).

While the view that optimal patient care should emerge from the integration of both clinical and biomedical knowledge is supported, it is also believed that consideration should be given to how biomedical knowledge is taught and what level of biomedical knowledge is useful to the practising clinician (Patel & Kaufman 1995; Boshuizen & Schmidt 1995). For knowledge to be accessible it must be acquired in the context for which it will be used (Rumelhart & Ortony 1977; Cervero 1988; Shepard & Jensen 1990). Therefore, in the attempt to catch up with the pain sciences, care is needed to continually link biomedical knowledge with its clinical significance, with emphasis placed on principles and concepts while accepting that precise details of the complex and still not fully understood underlying mechanisms are less relevant to the practising clinician.

### **How to promote critical yet creative clinical reasoning**

If it is accepted that physiotherapists should be thinking clinicians who question, explore and reflect, then consideration needs to be given as to what can be done to improve therapists' clinical reasoning. Reasoning needs to be critical yet creative and make use of both clinical and biomedical information. There are a number of measures which could promote this style of reasoning including increasing awareness of reasoning processes, broadening perspectives beyond diagnostic reasoning, creating greater awareness of reasoning errors, encouraging greater use of inquiry strategies such as hypothesis testing to prove or disprove hypotheses, improving knowledge and organisation of knowledge, and encouraging regular use of reflection.

### *Beyond diagnostic reasoning*

Rather than solely focusing assessment on diagnosis, or identifying the source of the symptoms and focusing treatment on the injured tissues, a broader perspective of clinical reasoning is needed. Cheryll Mattingly (1991), an anthropologist who has contributed significantly to clinical reasoning research in occupational therapy, has criticised the diagnostic focus of medical clinical reasoning. Mattingly (1991) suggests that diagnostic reasoning is insufficient to account for the clinical reasoning of clinicians whose role it is to interact personally in the rehabilitation process. Direct physical involvement in the patient's treatment requires sensitivity to the individual context of each patient's presentation.

Mattingly (1991) has used the concept of a patient's 'illness experience' to encourage this broader perspective. She defines illness experience as 'the meaning that a disability takes on for a particular patient, that is, how disease and disability enter the phenomenological world

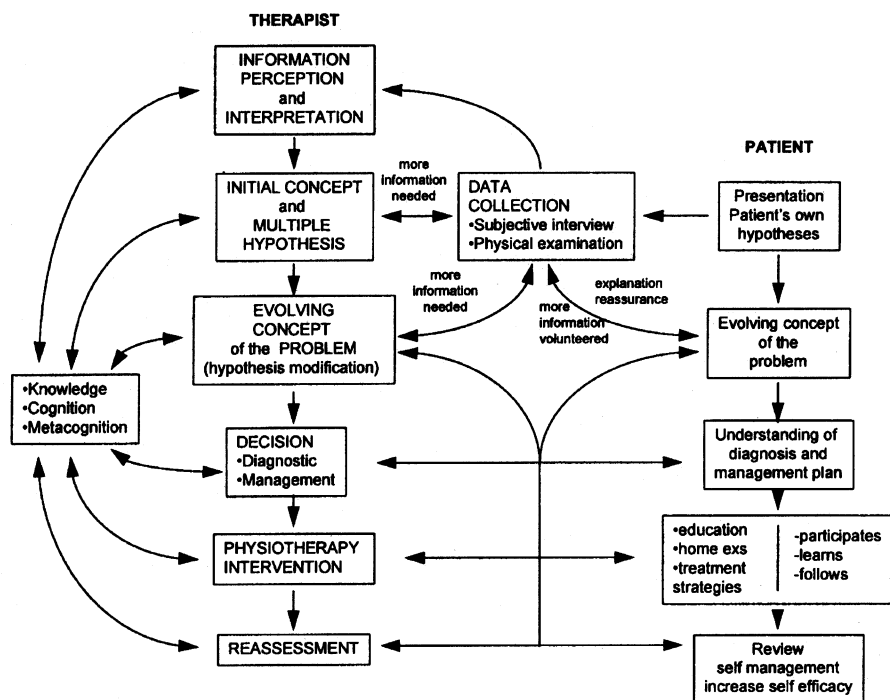


Fig. 2—Cooperative decision making between patient and therapist (Edwards 1995).

of each person'. The individual meaning patients give to their disability or what may be a better term, their 'pain experience' will significantly influence emotions, expectations, goals, motivation and involvement in the treatment process. It is inadequate to view patient assessment as merely being an exercise in problem solving where the aim is to identify and label or diagnose the causative factor. A non-client directed style of patient assessment, where the examiner follows a predetermined, structured course of inquiry and is insensitive to the patient's personal frame of reference or context, also tends to exclude the patient from the decision making. But if the patient is not an active participant in the process and if the context of the patient's dysfunction and pain are not truly considered, the problem will never be fully understood and the outcome will always be jeopardised.

To guide the continual improvisation which occurs in treatment, clinicians must be able simultaneously to perceive and interpret multiple physical, psychological and social patient cues and adjust their treatment and responses to the evolving treatment session. This form of dynamic interaction requires more than strong biomedical knowledge. Successful management requires an understanding of how the disability has impacted on the patient's life.

The significance of the physical, psychological and social aspects of an individual's problem to successful management will vary. On the one hand, clinical reasoning through some problems will appear to be pure diagnostic reasoning. For example, a patient with an acute antalgic posture of the neck can often be successfully treated in one or two appointments. Here diagnostic rea-

soning is essential to recognise correctly the clinical syndrome and subsequently choose an effective treatment. The patient's personal life will often not be significantly affected and thus this is not a major issue in the clinician's reasoning. In contrast, in most neurological, cardiorespiratory and many orthopaedic problems it is essential to understand the patient's unique pain experience and treat the whole person rather than the disability. Perhaps the best example in the orthopaedic area is the 'chronic pain patient'. The complexity of many chronic pain presentations lies not only in the multi-structural involvement and extent of pathology which commonly exists, but also the significant disturbance to all aspects of these individuals' lives which in turn has direct and indirect consequences on their pain and disability. Clinical reasoning with these patients must include attention to their pain experience.

Figure 2 (Edwards 1995) reflects the importance of the patient's role in the clinical reasoning process. Patients have their own hypotheses regarding what their problem might be and what information they consider relevant and worth volunteering. Through a process of explanation, reassurance and shared problem solving, the 'enlightenment' of the therapist regarding diagnosis and management of a problem is paralleled by the 'enlightenment' of the patient regarding his or her own problem or situation and ability to do something about it. This increase in patient, and on occasion family, understanding and self efficacy, enhances the likelihood that additional information will come forward. Responsibility is shared between patient and therapist, with the patient being encouraged to take an active role in the management, increasing the likelihood of contin-

ued self-management. This inclusion of the patient in the problem solving and decision making process enhances the therapist's ability to understand the problem including the effect it has on the patient's life.

#### *Organisation of knowledge – hypothesis categories*

In addition to this broader perspective of clinical reasoning, the use of hypothesis categories has been proposed to encourage clinicians to consider and reflect on their clinical decision making and contemplate both clinical and biomedical sources of information (Jones 1992; Jones et al 1995).

The following hypothesis categories are suggested as a means of organising clinicians' knowledge and clinical decision making:

1. Source of the symptoms (including pathology of the target tissue(s))
2. Mechanism of the symptoms
3. Contributing factors
4. Precautions and contraindications to physical examination and treatment
5. Management and treatment
6. Prognosis

The source of the symptoms refers to the actual structure or target tissue from which the symptoms are emanating with particular attention, where possible, to the pathology present within that structure. Joints, muscles, soft tissue and even nerves are examples of target tissues which can be injured and give rise to pain.

The mechanism of the symptoms relates to the nervous system and specifically to how pain messages are being initiated and maintained. We are all familiar with the basic mechanism operating when a high intensity stimulus, such as a pin prick, activates high threshold primary afferent nociceptors and results in pain. The same mechanism is in operation with acute injuries where injury to target tissues such as ligaments, muscles and even the connective tissue surrounding nerves will result in mechanical and/or chemical stimulation of nociceptors in what has been called nociceptive pain. However, this is a simple account of what actually occurs and is on its own insufficient to explain the clinical presentation we typically see. With acute injuries, normally non-noxious low threshold stimuli now become painful and the area of sensitivity surrounding the injury often extends well beyond the borders of the actual tissue damage. Understanding these phenomena requires biomedical knowledge of concepts such as peripheral and central sensitisation and neurogenic inflammation.

The second subcategory, peripherally evoked neurogenic symptoms, refers to symptoms that originate from neural tissue outside the dorsal horn or cervicotrigenial nucleus such as nerve root compression or peripheral nerve entrapment. Both nociceptive pain and peripherally evoked neurogenic symptoms have a familiar pattern of presentation to most clinicians with a

predictable stimulus–response relationship enabling aggravating and easing factors to be quickly identified by patient and clinician.

The third subcategory within mechanism of symptoms, centrally evoked symptoms, is only just being understood within the pain sciences and even more recently physiotherapists are attempting to identify the clinical features associated with this mechanism. Suffice to say in this brief reference to pain mechanisms, that with centrally evoked symptoms, actual pathology exists within the central nervous system resulting in altered central nervous system processing. Here the symptoms provoked from a past target injury can be maintained even after the original injury has healed. The symptoms no longer behave with stimulus–response predictability.

The fourth subcategory refers to symptoms such as sweating, swelling, skin redness or maintained pain that are associated with autonomic, particularly sympathetic nervous system disturbance and motor effects such as spasm and dystonias associated with spinal reflexes.

The last subcategory refers to the affective or emotional influences on pain which are being increasingly better understood in terms of their neurological consequences which, via descending central nervous system input, have significant potential to alter pain perception and behaviour.

Contributing factors are any predisposing or associated factors involved in the development or maintenance of the patient's problem. These include environmental, emotional, physical, and/or biomechanical factors. Hypotheses regarding precautions and contraindications to physical examination and treatment serve to determine the extent of physical examination that may safely be undertaken and whether physical treatment is indicated, and if so, whether there are any constraints to physical treatment (e.g. pain provoking versus non-provocative treatment techniques). Management and treatment relates to hypotheses for the overall health of the patient as well as specific physiotherapy measures and techniques which would be considered. Prognosis should be considered with regard to the patient's broader prospects for recovery and return to function.

These hypothesis categories were devised from the perspective of physiotherapists working with patients having neuro-musculo-skeletal dysfunction. They are not proposed as a definitive list and should always be evaluated for usefulness and representativeness. The hypothesis subcategories within mechanism of symptoms, for example, are an attempt to relate the present state of knowledge in the pain sciences to clinical practice. Physiotherapists must continually search for the clinical features associated with the clinical patterns which exist within each of the hypothesis categories, and similarly identify patterns of management which are appropriate for the varying clinical presentations. While other hypothesis categories might be more appro-

priate for different health professionals or when working with different patient populations, clinicians are encouraged to consider the reasoning behind their inquiries, tests and interventions. From this reasoning it should be possible broadly to identify categories of clinical judgements (i.e. hypotheses) which need to be made through the problem solving process. This provides a framework from which experts can be asked to expound on their clinical insight and provides a structure through which clinical patterns can be questioned and new patterns learned.

#### *Promoting reasoning through reflection and lateral thinking*

Searching for these patterns within the patient's structural, physiological, and psychological clinical presentation requires hypothesis generation, hypothesis testing, re-assessment of interventions made and most importantly 'Reflection!'. It is easy in a busy clinical practice to function almost automatically on pattern recognition. Familiar patient presentations lead to treatment approaches that have worked in the past and little reflection occurs. Without time to reflect and some guide such as hypothesis categories on what to reflect, many clinicians will fail to learn new clinical patterns and their reasoning and practice will increasingly be based on clinical routines with little relationship to biomedical knowledge. Without reflection, clinicians will continue with the same rate of clinical success, not learning where changes in practice would improve their success.

Lastly we need to continue to generate new ideas. While some individuals appear to be naturally creative thinkers, anyone can engage in lateral thinking once they become aware of how they think at present. The cyclical clinical reasoning process portrayed in Figure 1 is essentially a diagram of logical, vertical thinking. By contrast, lateral thinking involves a restructuring and an escape from old patterns as well as the creation of new ones – it is concerned with looking at things in a different way and the generation of new ideas. To promote your own creative, lateral thinking you must first be able to recognise the dominant idea or approach you are presently taking toward a problem. Without this any new idea you trial will only be a variation on the same theme. Once you recognise the focus of your present approach to a problem, you can then look outside it to explore alternative ideas or solutions.

## CONCLUSION

In conclusion, reflective clinicians and researchers who have both logical and creative thinking abilities will continue to contribute to the advancement of pain management. We need to be able to draw from what is known in the biomedical world and become more familiar with relevant knowledge outside our respective pro-

fessions while not losing touch with patients themselves who, regardless of what the known body of knowledge may tell us, can still provide us with invaluable information on how best to help their problem. Clinicians are increasingly being challenged to research and substantiate their clinical beliefs. This will greatly assist in advancing our understanding of what we do and assist us in identifying truly effective treatments from fad, fashion or placebo. However, clinicians must never lose the ability to treat patients empirically and explore patient problems through assessment and treatment.

Clinical reasoning in pain management in the future should include increasing open mindedness and breadth of thinking styles. Where practice is dominated by reasoning-deficient adherence to routines or politically motivated allegiance to one approach, we need greater critical thinking and theoretical pluralism. Rule-governed behaviour can contribute to efficiency and effectiveness of health care, but it must be accompanied by attitudes of curiosity and strategies of critical and reflective thinking. Where practice is dominated by critical thinking, we need greater creative and lateral thinking.

## Acknowledgements

This article, with minor changes, has been reprinted with kind permission of Butterworth-Heinemann from a paper published in the proceedings of the inaugural 'Moving In On Pain' Conference held in Adelaide, South Australia from 18–21 April 1995. Some sections have been extracted from a chapter by Jones, Jensen and Rothstein 'Clinical Reasoning in Physiotherapy'. In: Higgs J, Jones M (Eds) *Clinical Reasoning in the Health Professions*. Butterworth-Heinemann, London, p72–87.

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