International Journal of Osteopathic Medicine (2013) xxx, xxx–xxx

ELSEVIER

International Journal of Osteopathic Medicine

www.elsevier.com/ijos

Developing competence in diagnostic palpation: Perspectives from neuroscience and education

Jorge E. Esteves [a,*], Charles Spence [b]

[a] British School of Osteopathy, 275 Borough High Street, London SE1 1JE, UK
[b] Crossmodal Research Laboratory, Department of Experimental Psychology, Oxford University, UK

Received 14 December 2012; accepted 1 July 2013

KEYWORDS
Diagnostic palpation;
Educational neuroscience;
Osteopathic education;
Clinical reasoning

Abstract Palpation plays a central role in osteopathic clinical decision making, yet it is one of the hardest clinical skills to develop, teach, and assess. In fact, it could be argued that osteopaths literally diagnose with most of their senses. Information conveyed by the osteopath's different senses is processed and interpreted in his/her brain, taking into consideration the relevant anatomical, physiological, and pathological knowledge, osteopathic models of care, and the osteopath's own clinical experience. It has been claimed that expert clinicians demonstrate palpatory literacy to the extent that they often speak of having 'listening' or 'seeing' hands. Considering the plastic nature of the human brain, we argue that that the development of palpatory diagnostic expertise is likely to be associated with behavioural, neuroanatomical, and neurophysiological adaptive changes. Building upon the initial findings of our ongoing research examining the neural and behavioural correlates of diagnostic expertise in osteopathy and on evidence from the fields of cognitive neuroscience, experimental psychology, and medical cognition, this paper proposes ways in which the development of competence in diagnostic palpation can be optimised. We propose that as students progress through their programme of study, they should be encouraged to use available opportunities to experience normal and altered patterns of structure and function; and reflect on the validity and reliability of their diagnostic judgements.
© 2013 Elsevier Ltd. All rights reserved.

Introduction

Palpation plays a central role in osteopathic clinical decision making, in particular with regard to the identification of paraspinal soft tissue texture changes and altered intervertebral joint mobility.[1]

* Corresponding author. Tel.: +44 (0) 20 7089 5310.
E-mail addresses: j.esteves@bso.ac.uk, osteojorge@gmail.com (J.E. Esteves), charles.spence@psy.ox.ac.uk (C. Spence).

1746-0689/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ijosm.2013.07.001

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

Altered tissue texture and joint mobility are regarded as the two most relevant clinical signs for the diagnosis of somatic dysfunction.[1] Even though the existence of somatic dysfunction and the reliability of detecting its existence have been questioned [e.g., Refs. 2—4], the concept continues to have an important place in osteopathic curricula in both the UK and worldwide. In fact, despite this ongoing debate, the somatic dysfunction hypothesis has been endorsed by the WHO in their benchmark document for training in osteopathy.[5] Although the somatic dysfunction hypothesis requires further empirical validation, the reliance on palpation as a diagnostic tool, dictate improvements in the reliability of this clinical examination technique. Apart from the diagnosis of somatic dysfunction, osteopaths commonly use palpation to detect clinical signs of disease, which requires the patient to undergo further investigations. Diagnostic palpation is, therefore, an important part of an osteopath's clinical competence profile. Notwithstanding this, it is one of the hardest clinical skills to develop, teach, and assess.

Educators are tasked with providing students with relevant and effective teaching and learning experiences, which enable them to successfully make the transition from novices to competent autonomous health care practitioners. Although palpation plays a central role in osteopathic diagnosis and patient care, clinicians literally diagnose with most of their senses. They hear what their patients have to say, they observe their appearance and how they move, they palpate their anatomical structures, and they detect any peculiar smell that may be caused by serious pathology. Information conveyed by the osteopath's different senses is processed and interpreted in his/her brain, taking into consideration the relevant anatomical, physiological, and pathological knowledge, osteopathic models of care, and the osteopath's own clinical experience. Clinical experience linked to their own interpretation of osteopathic philosophy and principles is likely to shape their style of clinical practice and approach to patient diagnosis and care.

Clinical education plays a central part in both the development of students' clinical competence, and in shaping their future style of practice. Typically using an apprentice-style learning model, osteopathic clinical tutors are tasked with the mission of facilitating the students' development of clinical reasoning, and the integration of professional and biomedical knowledge into the clinical setting.[6] According to Wallace, students are seen to be apprentices to more experienced clinicians. Typically, these clinicians have been in clinical practice for a considerable number of years, and have developed their professional knowledge and competence to the level of expert practitionership. Interestingly, it is not uncommon to find students who report that their tutors on occasion, are unable to explain their clinical findings and decision making process. It seems that at times, some of their decisions are primarily based on clinical intuition. In particular, expert clinicians seem to be able to locate areas of dysfunction, which leave students perplexed, and, at times, fascinated. On this point, Mattingly[7] has argued that clinical reasoning is a highly imagistic and deeply phenomenological mode of thinking, which is based on tacit knowledge acquired through clinical experience. For example, in the context of a clinical examination, expert clinicians seem to be able to make decisions which are based upon the perception of wholeness, rather than on a focus on isolated individual sections.[8(p234)]

However, one should ask: how is this level of expertise achieved? Glaser[9(p88)] has argued that expertise is *"proficiency taken to its highest level"*. In their everyday working activities, experts use thinking strategies that are largely shaped by their ability to perceive large and meaningful patterns. In contrast, novices are only able to recognise smaller, and less developed patterns.[9(p91)] Feltovich et al.[10(p57)] have argued that expertise constitutes an adaptation, and its development is intimately associated with the ability to gather an extensive set of skills, knowledge, and mechanisms that monitor and control cognitive processes to efficiently and effectively perform within a specific domain. Experts are therefore able to re-structure, re-organise, and refine their representation of knowledge, skills, and actions in order to effectively operate in their workplace.[10]

The adaptive processes associated with the development of expertise are likely to have profound effects on the nature of brain processing.[11(p675)] Learning is the result of experience and in some cases occurs by the rewiring of neural pathways, i.e., neuroplasticity.[12] Considering the plastic nature of the human brain, it can be argued that the development of palpatory diagnostic expertise is likely to be associated with behavioural, neuroanatomical, and neurophysiological adaptive changes. Achieving expertise within a specific domain of professional practice, art, or sport is, however, a lengthy process. There is now a general consensus amongst researchers in the field of expertise development that it takes approximately 10,000 h of intense deliberate

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

ARTICLE IN PRESS

practice to become an expert within a chosen domain [e.g., Ref. 13]. In clinical practice, it has been suggested that expertise is partially developed through clinical reasoning.[14–16] Understanding the way in which expert osteopaths process and interpret diagnostic information is therefore important to the implementation of effective teaching and learning strategies.

Building upon the initial findings of our ongoing research examining the neural and behavioural correlates of diagnostic expertise in osteopathy[17] and on evidence from the fields of cognitive neuroscience, experimental psychology, and medical cognition, this paper proposes ways in which the development of competence in diagnostic palpation can be optimised. It is important to highlight that the cognitive neuroscience and education nexus has been highlighted in the literature as a possible future avenue for research in the field of education [e.g., Refs. 18,19]. Although little has been attempted as a means of using cognitive neuroscience as a future avenue for research in the field of medical cognition, suggestions have nevertheless been made as to the value of this approach.[20,21]

Experience-based neuroplasticity, palpation and decision making

Authors in the field of osteopathy have claimed that expert clinicians demonstrate palpatory literacy to the extent that they often speak of having 'listening' or 'seeing' hands.[22] However, how do osteopaths reach this level of expertise? The initial results of our research demonstrate that the development of expertise in diagnostic palpation in osteopathy is associated with changes in cognitive processing style.[17] Diagnoses of tissue dysfunction made by experts are largely influenced by top-down, non-analytical reasoning (*e.g.* pattern recognition). Students, by contrast, are likely to rely primarily on bottom-up sensory processing from vision and haptics (i.e., touch and proprioception). Perceptual judgements of tissue dysfunction are, in this case, primarily supported by analytical reasoning (*e.g.* deductive reasoning).

The way in which expert osteopaths gather diagnostic data through their senses, process information, and make clinical decisions might all reasonably be expected to be shaped by their extensive clinical experience. This hypothesis requires, however, a thorough consideration of adult neuroplasticity. Long-held beliefs that cortical and subcortical structures were unchangeable after childhood have been challenged by the evidence emerging from the growing number of studies investigating experience-based neuroplasticity. Pascual-Leone et al.[23] have argued that all neural activity, including mental practice, leads to change, which results from plasticity; and factors such as experience, functional significance and environmental pressures play a critical role. Bukach, Gauthier, and Tarr[24] have argued that studying the cognitive and neural correlates of expertise provides researchers with a unique window into the functional plasticity of mind and brain. On this point, Munte, Altenmuller, and Jancke[25] proposed that the musician's brain provide an ideal model for studying experience-driven neuroplasticity.

William James[26] was the first author to introduce the concept of plasticity to the field of psychology. Adult neuroplasticity has been regarded as an evolutionary measure that allows the nervous system to escape the limitations of its own genome, and hence adapt to physiological changes, environmental challenges, and experiences.[23] Therefore, neuroplasticity should be regarded as an ongoing state of the nervous system throughout the life span that leads to changes in human behaviour.[23] Mercado[27(p153)] postulated that cognitive plasticity is nevertheless dependent on "*1) the availability of specialised cortical circuits; 2) the flexibility with which cortical activity is coordinated; 3) the customisability of cortical networks*".

Extensive clinical practice over a number of years both at the undergraduate level and later in professional practice can undoubtedly modify human behaviour expressed in the form of clinical competence. In particular, it can be argued that the nervous system of osteopaths will undergo alterations at both the functional and structural levels, which result from extensive exposure to multisensory experiences and ongoing learning and decision making processes. We argue that it is important that educators understand these processes in order to effectively support the development of their students' diagnostic capabilities.

The role of neuroplasticity in the development of expertise has now been explored in a numbers of contexts and professional groups. Bor and Owen[28] reviewed recent evidence from neuroimaging studies on the neural correlates of expertise and found that the acquisition of expertise involves a network of frontal and parietal regions, in particular the Dorsolateral prefrontal cortex (DLPFC) and Posterior parietal cortex (PPC). They suggested that these areas play a primary role in coordinating activity in content-specific areas. Although their

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

ARTICLE IN PRESS

findings fail to provide evidence regarding those areas involved in learning, they postulated that they may reflect the important role of chunking in the development of expertise.

Evidence concerning the neural correlates of medical expertise is, however, still preliminary. In radiology, Haller and Radue[29] have demonstrated that expert radiologists appear to have a modified visual system with evidence of the selective enhancement of brain activation associated with the viewing of radiological images. These results may, however, be simply attributed to enhanced visual attentional selectivity. More recently, Harley et al.[30] used neuroimaging techniques to measure neural activity in both Lateral occipital cortex (LOC) and fusiform gyrus in expert radiologists as they diagnosed abnormalities in chest X-rays. They found a strong correlation between expertise and neural activity in the fusiform gyrus, and a negative correlation between expertise and activity in the LOC. They suggested that training in radiology may lead to an ability to engage the fusiform gyrus whilst suppressing existing neural representations. The involvement of the fusiform gyrus and LOC may nevertheless be attributed to top-down visual mental imagery processes occurring in clinical decision making.

Further evidence emerges from Leff et al.'s work,[31] who used fNIRS (Functional near-infrared spectroscopy) to investigate the effect of surgical expertise on cortical activity. Using a knot-tying task based on a real-life surgical technique, they observed decreased activation of the prefrontal cortex (PFC) in expert surgeons whilst performing the knot-tying task. By contrast, increased cortical activity in the PFC was observed amongst the 'surgical' novices. Leff et al. have argued that alterations in cortical activity, in particular the decreased activation of the PFC observed in expert surgeons, are likely to be associated with a continuum through phases of learning in surgical skills.

Although research on the neural correlates of medical expertise is still in its infancy, more extensive and robust evidence can be found in others areas of professional practice. For example, in the field of music, Elbert et al.[32] have demonstrated a significant enlargement in the cortical representation of the left hand in the somatosensory cortex of string players; therefore supporting the hypothesis that experience contributes to cortical plasticity. These findings emerged from a neuroimaging study comparing activations in the somatosensory cortices of experienced musicians and non-musicians, to tactile stimulation of the digits of both hands.

The effects of long-term professional training on adaptive neuroplasticity have also been widely investigated in London taxi drivers [e.g. Ref. 33, for a review]. For example, using structural magnetic resonance imaging scans, Maguire et al.[34] compared the brains of experienced taxi drivers with those of non taxi drivers. Their findings revealed that the taxi drivers had significantly larger posterior hippocampi. As the posterior region of the hippocampus is involved in storing spatial representation of the environment, Maguire et al. concluded that this cortical area can expand as a result of extensive exposure to environmental demands. The authors argued that their results demonstrate that the healthy human brain has capacity for local experience-driven neuroplasticity. Despite the plausibility of their argument, it can however be argued that some of these taxi drivers may have already possessed large hippocampi, before they started their professional careers. Causality should therefore be interpreted with caution.

Arguably, the brains of expert osteopaths may undergo structural and functional changes resulting in, for example, enlarged cortical representation of their hands, or leading to an increased efficiency in multisensory integration.

Promoting the development of competence in diagnostic palpation

An understanding of cognitive architecture and how information is processed by the nervous system enables educators to optimise teaching and learning strategies, in particular those aimed at dealing with the occurrence of diagnostic errors.[35,36] In the context of osteopathy, an understanding of how clinical experience shapes the way information is processed and how diagnostic judgements are made, should enable educators to critically appraise the way in which core clinical skills such as diagnostic palpation, are taught, practised, and assessed. Improvements in the development of palpatory competence may be achieved by ensuring that the teaching of palpation is not dissociated from the development of clinical reasoning capabilities. In this section, we propose a number of teaching and learning strategies which may effectively support the development of this clinical skill.

In the first year of their undergraduate education, students start learning and practising a variety of clinical examination techniques, including basic procedures of static patient observation in standing and sitting positions, and palpatory

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

ARTICLE IN PRESS

techniques designed to evaluate, for example, soft tissue texture and compliance. The various clinical examination procedures are typically taught in the context of osteopathic evaluation and technique classroom based activities. Teaching and learning strategies include a combination of practical demonstrations and the delivery of theoretical knowledge regarding the purpose and underpinning rationale for the various clinical examination procedures. Students typically practise these skills on their colleagues under the supervision of their tutors. In this context, whilst practising on their colleagues, students are encouraged to develop their haptic and visual skills by drawing on their developing anatomical, physiological, and biomechanical knowledge. Apart from ensuring that students develop safe and effective clinical skills, it is common for tutors to support them in the interpretation of their findings. Tutors typically do this by examining the model themselves, and by providing the students with an interpretation of their own findings. Although it could be argued that this approach enables the students to have a frame of reference for their own findings, it may nevertheless be responsible for a premature use of non-analytical processing in diagnostic palpation. Consequently, students may start developing heuristics strategies (i.e., short-cuts) in their clinical examination before they have sufficient knowledge, skills, and experience to interpret their findings. Arguably, this may contribute to the poor reliability of diagnostic palpation.

In order to improve this situation, we would argue that students at the early stages of their professional education should be encouraged to explore visual, tactile and proprioceptive sensations without the need of a clinical interpretation of their findings. By providing students with a safe environment for the initial development of their haptic and visual skills, educators are supporting a progressive modifiability of their students' sensory systems. The emphasis at this stage of their development should be on bottom-up processing (i.e., ascending mechanisms). In fact, the exposure to a range of visual and haptic sensations in the context of a clinical examination is likely to contribute to an expansion of the cortical maps in, for example, the somatosensory cortex. The expansion of the cortical representation for the digits in response to training is a well-established phenomenon in professional groups such as musicians [e.g., Refs. 32,37]. Recently, Willard et al.[38(p221)] have claimed that a similar enlargement of the cortical map of the digits is likely to occur in the cortex of an osteopath as a result of training in diagnostic palpation. However, it is important that students be allowed to explore sensory cues in a progressive manner, i.e. without the need for perceptual judgements and by giving attention to one single modality of input at a time. For example, in the assessment of soft tissue texture and compliance, students may be encouraged to focus their attention on the haptic modality in order to reduce the sensory uncertainty associated with the availability of haptic and visual cues. Vision, in this case, may be occluded; however, it is critical that the students' eyes are kept open as a means of limiting the use of mental imagery at the early stage of their educational development.

As they become more confident in their exploration of unimodal sensory experiences, students should then be exposed to multisensory experiences. For example, they should be encouraged to simultaneously use vision and haptics in the exploration of soft tissue texture and compliance, with their colleagues in a variety of positions, including standing, sitting and prone. This approach would enable students to start developing their ability to combine data from different sensory modalities, and to initiate the process of critical thinking in patient evaluation. We believe that in order to equip students with the skills of criticality required to dealing with the uncertainty of palpatory findings, students need to understand concepts of probabilistic thinking, and the sensitivity and specificity of various clinical tests. Ideally, this knowledge should be acquired alongside the development of their clinical examination skills. Although first year undergraduate students may fail to see the relevance of this knowledge of biostatistics at such an early stage of the their professional development, Rao and Kanter[39] have recently proposed that an evidence-based medicine curriculum based on physician numeracy provides students with a foundation for using biomedical and clinical knowledge in their clinical decision making. From an osteopathic perspective, it could be argued that this approach would also enable students to think critically about concepts relevant to osteopathic clinical decision making, namely the validity of the somatic dysfunction concept, and the reliability associated with its diagnosis. Furthermore, a basic understanding of Bayes rules provides a foundation for multisensory perception in the diagnosis of somatic dysfunction.

Tutors play a critical role in mediating learning and consequently promoting cognitive modifiability. Rather than imposing their own models of diagnosis on students, tutors should, where appropriate, examine the patient/model in

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

collaboration with the students and engage in discussions regarding the nature of their sensory experiences. Importantly, tutors should ensure that students engage in discussions regarding the reliability of visual and haptic cues and their potential intersensory biasing effects in the assessment of soft tissue texture, postural asymmetry, and intervertebral joint mobility. Tutors should act as coaches, who monitor the students' questions and responses, commenting on their relevance and accuracy.[40] Importantly, tutors should create a learning environment whereby the process of demonstration, scaffolding, and communication, students can confidently develop their ability to use vision and haptics in a clinical examination context, until it becomes internalised as an independent achievement. Learning, and arguably cognitive modifiability, occurs in the zone of proximal development.[41,42] To this end, tutors should create increasingly challenging situations in order to promote learning. With increasing confidence in their developing clinical skills, it is then important that students start drawing on their anatomical knowledge when practising, for example, diagnostic palpation.

Apart from the exposure to high-fidelity learning experiences such as those associated with the practise of diagnostic palpation on other students or patients, students can also benefit from developing their visual, haptic, and spatial awareness skills in other learning environments. For example, the use of haptic force-feedback technology has, in recent years, taken a central role in the development of palpatory skills in medical and veterinary education [e.g., Refs. 43,44]. Although the use of haptic force-feedback technology is generally beyond the reach of most osteopathic academic institutions in the UK, researchers at the Ohio University College of Osteopathic Medicine have successfully developed a haptic simulator (VHB) for palpatory training of first year osteopathic students.[45] The preliminary results from their research have shown that the use of the VHB improved speed and diagnostic accuracy of first year students in the detection of altered surface compliance.[46] Apart from high-fidelity simulations, haptic force-feedback devices can also be used for computer games that enable students to develop core palpatory skills. On this point, Baillie et al.[47] have reported on the development of a set of computer games designed to develop veterinary students' skills of determining object size, shape and firmness, as well as thinking in 3D. Arguably, these core palpatory skills are equally relevant to osteopaths. Taken together, the preliminary evidence from the use of haptic simulators in medical and veterinary education suggests that the reliability of diagnostic palpation in osteopathy could be improved with their adoption in osteopathic education. This is, perhaps, an area where osteopathic academic institutions should consider investing resources in order to facilitate the development of their students' clinical competence profile.

The skill of thinking in 3D has been considered by doctors and veterinarians as a core palpatory capability, in particular with regard to processing sensory information gathered during an internal examination, or whilst building a 3D mental picture of the anatomy.[47] In osteopathy, first year undergraduate students are required to develop a detailed knowledge and understanding of the three-dimensional nature of the body regions to assist visualisation of anatomical structures when practising clinical examination procedures such as palpation. Apart from drawing upon their knowledge of anatomy, students are also typically encouraged to use their developing knowledge of physiology and biomechanics to visualise the application of these clinical skills. The development of visuo-spatial thinking is intimately associated with the mental imagery and top-down cognitive processing, and the development of clinical expertise. On this latter point, Fernandez et al.[48] have recently found evidence that spatial cognitive capabilities are central to the work in clinical anatomy, and both professional education and clinical experience contribute to their further development. Considering the central role of biomedical knowledge, in particular the knowledge of clinical anatomy in osteopathic clinical decision making, it can be argued that educators should give due attention to the development of their students' spatial cognitive capabilities at the early stage of their programme of study.

Once students have acquired sufficient experience in clinical examination to feel confident in their own sensory skills, they should start interpreting their visual and haptic findings in a collaborative learning environment where tutors play a leading supporting role. Tutors should ensure that the top-down processing associated with the perception of signs of normal and altered function does not completely override their students' sensory experiences. To this end, it is critical that students use a combination of analytical and non-analytical reasoning strategies to interpret their findings. Students should engage in discussions regarding the nature of their findings, concepts of causality and probability.[40]

The development of spatial cognitive capabilities, in particular those related to the visualisation of anatomical structures and their

ARTICLE IN PRESS

associated underpinning biomechanics can be enhanced by encouraging students to palpate with their eyes closed; for example, in the assessment of soft tissue texture and intervertebral joint mobility in the cervical spine with their model lying in a supine position. Although the results from our research suggest that eye closure and its associated mental imagery and multisensory processing is likely to enhance the perception of somatic dysfunction,[17] tutors should nonetheless critically consider that perception can be influenced by, for example, untested models of structure-function and dysfunction. On this point, Sommerfeld et al.[49] highlighted the possibility that with regard to osteopathy in the cranial field, the perception of the primary respiratory mechanism could be influenced by the use of mental imagery. Typically, tutors are experienced clinicians with specialist interests in various areas of osteopathic care, who may influence the way in which students interpret their findings. Through a process of demonstration, scaffolding, and discussion, tutors should encourage students to critically appraise the nature of their findings, their own cognitive processes, and claims made by authors in the field of osteopathy. Interestingly, Kassirer[40] argued that in Problem based learning (PBL) and Case based learning (CBL) activities, tutors should refrain from converting the session into a lecture on their area of expertise. Instead, in situations of complexity, students should be encouraged to seek critical evidence from other sources, including published research. Arguably, this approach enables students to develop metacognitive (i.e., higher order thinking) skills which are essential for autonomous clinical practice.

As students progress through their programme of study, they should be encouraged to use available opportunities to experience normal and altered patterns of structure and function, and reflect on the validity and reliability of their diagnostic judgements. Apart from drawing upon their knowledge of anatomy and human mechanics, students should further develop their clinical skills by taking into consideration the pathophysiological tissue states, postural dysfunction, and possible psychosocial issues contributing to pain and disability. The development of visual and haptic patterns of function and dysfunction leads to what Parsons and Marcer[50] labelled as 'palpatory reference libraries'. Tactile memories are likely to be stored in the PPC and inferotemporal cortex.[38] The PFC, working in synergy with parietal and temporal cortical areas, would then create the osteopath's working memory (WM) of the tactile experience [see Refs. 38,51, on this point]. Willard et al.[38(p226)] have proposed that tactile memories are used to compare soft tissue feelings; and based on those memories, students develop a sense of normal and altered tissue texture.

The development of visual, tactile/haptic memories allows students to start making rapid diagnostic judgements based on the recognition of particular clinical features. Although this non-analytical reasoning is a feature of clinical expertise, and therefore likely to be the strategy commonly used in familiar situations; students should nevertheless be encouraged to consider the value of analytical reasoning in ensuring the reliability of their judgements, in particular in situations of clinical complexity. We believe that the use of PBL and CBL activities provide the ideal means to support the students' development of clinical competence. Critically, these PBL and CBL activities should include discussions centred on carefully selected clinical cases that are unfamiliar to both students and tutors.[40] By adopting real-life but complex case scenarios, educators are promoting the process of knowledge encapsulation and script formation, but also improving the students' ability to value the uncertainty and ambiguity of clinical data [Ref. 40, on the latter point]. Effective teaching should equip students with the ability to appraise their own performance and identify aspects of their reasoning and decision making where improvements may be required.[52]

Conclusion

Understanding the nature of expertise in diagnostic palpation has implications for the education of future osteopaths. Expertise development is a slow and discontinuous process. For example, students commonly refer to palpation as one of the hardest clinical skills to develop. It is not uncommon to find osteopathic students to whom it may take several years to develop confidence in their own palpatory skills. Improvements in the speed of this development may be achieved through the use of appropriate learning and teaching strategies given the level of expertise of the student.[53] Students' learning should be situated in a number of different contexts in order for it to be effective. Students have to develop knowledge and understanding regarding the practice of osteopathy, practical skills in the delivery of osteopathic care, and integrated skills of total osteopathic delivery in the clinical context. Diagnostic palpation plays a central role in osteopathic care. This paper aims to contribute towards the

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

design and implementation of teaching and learning strategies that best support the development and maintenance of clinical competence through the continuum from novice to expert. We argue that as students progress through their programme of study, they should be encouraged to use available opportunities to experience normal and altered patterns of structure and function; and reflect on the validity and reliability of their diagnostic judgements.

Statement of competing interests

JEE is a member of the International Advisory Board of the Int J Osteopath Med but was not involved in review or editorial decisions regarding this manuscript.

Author contributions

This article is based on JEE doctoral thesis, which was supervised by CS. JEE drafted the article; both authors approved the final version.

References

1. Fryer G, Johnson JC, Fossum C. The use of spinal and sacroiliac joint procedures within the British osteopathic profession. Part 1: assessment. *Int J Osteopath Med* 2010; **13**:143–51.
2. Fryer G, Bird M, Robbins B, Fossum C, Johnson JC. Resting electromyographic activity of deep thoracic transversospinalis muscles identified as abnormal with palpation. *J Am Osteopath Assoc* 2010;**110**:61–8.
3. Paulet T, Fryer G. Inter-examiner reliability of palpation for tissue texture abnormality in the thoracic paraspinal region. *Int J Osteopath Med* 2009;**12**:92–6.
4. Seffinger MA, Najm WI, Mishra SI, Adams A, Dickerson VM, Murphy LS, et al. Reliability of spinal palpation for diagnosis of back and neck pain: a systematic review of the literature. *Spine* 2004;**29**:E413–25.
5. WHO. *Benchmarks for training in osteopathy*. World Health Organization; 2010.
6. Wallace SS. Criticality, research, scholarship and teaching: osteopaths as educators – what makes a good teacher? *Int J Osteopath Med* 2008;**11**:52–5.
7. Mattingly C. What is clinical reasoning? *Am J Occup Ther* 1991;**11**:979–86.
8. Mattingly C. *Clinical reasoning: forms of inquiry in a therapeutic practice*. Philadelphia: F.A. Davis; 1994.
9. Glaser R. Expert knowledge and processes of thinking. In: McCormick R, Paechter C, editors. *Learning and knowledge*. London: Open University; 1999. p. 88–101.
10. Feltovich PJ, Prietula MJ, Ericsson KA. Studies of expertise from psychological perspectives. In: Ericsson KA, et al., editors. *The Cambridge handbook of expertise and expert performance*. Cambridge: Cambridge University Press; 2006. p. 41–68.
11. Hill NM, Schneider W. Brain changes in the development of expertise: neuroanatomical and neurophysiological evidence about skill-based adaptations. In: Ericsson KA, et al., editors. *The Cambridge handbook of expertise and expert performance*. Cambridge: Cambridge University Press; 2006. p. 653–82.
12. Longstaff A, editor. *Instant notes in neuroscience (BIOS instant notes)*. 2nd ed. Abingdon: Taylor & Francis; 2005.
13. Ericsson KA, Prietula MJ, Cokely ET. The making of an expert. *Harv Bus Rev* 2007;**85**:114–21. 193.
14. Higgs J, Jones MA. Clinical reasoning in the health professions. In: Higgs J, Jones MA, editors. *Clinical reasoning in the health professions*. Oxford: Butterworth-Heinemann; 2000. p. 3–14.
15. Rivett DA, Jones MA. Improving clinical reasoning in manual therapy. In: Jones MA, Rivett DA, editors. *Clinical reasoning for Manual Therapists*. Oxford: Butterworth-Heinemann; 2004. p. 403–19.
16. Carneiro AV. Clinical reasoning. What is its nature? Can it be taught? *Revista Portuguesa Cardiologia* 2003;**22**: 433–43.
17. Esteves JE. Diagnostic palpation in osteopathic medicine: a putative neurocognitive model of expertise. In: *Faculty of humanities and social sciences*. Oxford: Oxford Brookes University; 2011.
18. Goswami U. Neuroscience and education. *Br J Educ Psychol* 2004:1–14.
19. Geake J, Cooper P. Cognitive neuroscience: implications for education? *Westminster Stud Educ* 2003;**26**:7–20.
20. Talbot M. Good wine may need to mature: a critique of accelerated higher specialist training. Evidence from cognitive neuroscience. *Med Educ* 2004;**38**:399–408.
21. Norman GR. The epistemology of clinical reasoning: perspectives from philosophy, psychology, and neuroscience. *Acad Med* 2000;**75**:S127–35.
22. Kappler RE. Palpatory skills: an introduction. In: Ward R, editor. *Foundations for osteopathic medicine*. Baltimore: Williams & Wilkins; 1997. p. 473–7.
23. Pascual-Leone A, Amedi A, Fregni F, Merabet LB. The plastic human brain cortex. *Annu Rev Neurosci* 2005;**28**: 377–401.
24. Bukach CM, Gauthier I, Tarr MJ. Beyond faces and modularity: the power of an expertise framework. *Trends Cogn Sci* 2006;**10**:159–66.
25. Munte TF, Altenmuller E, Jancke L. The musician's brain as a model of neuroplasticity. *Nat Rev Neurosci* 2002;**3**: 473–8.
26. James W. *The principles of psychology*. New York: Henry Holt; 1890.
27. Mercado E. Cognitive plasticity and cortical Modules. *Curr Dir Psychol Sci* 2009;**18**:153–8.
28. Bor D, Owen AM. Cognitive training: neural correlates of expert skills. *Curr Biol* 2007;**17**:R95–7.
29. Haller S, Radue EW. What is different about a radiologist's brain? *Radiology* 2005;**236**:983–9.
30. Harley EM, Pope WB, Villablanca JP, Mumford J, Suh R, Mazziotta JC, et al. Engagement of fusiform cortex and disengagement of lateral occipital cortex in the acquisition of radiological expertise. *Cereb Cortex* 2009;**19**: 2746–54.
31. Leff DR, Elwell CE, Orihuela-Espina F, Atallah L, Delpy DT, Darzi AW, et al. Changes in prefrontal cortical behaviour depend upon familiarity on a bimanual co-ordination task: an fNIRS study. *Neuroimage* 2008;**39**:805–13.
32. Elbert T, Pantev C, Wienbruch C, Rockstroh B, Taub E. Increased cortical representation of the fingers of the left hand in string players. *Science* 1995;**270**:305–7.

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001

ARTICLE IN PRESS

33. Woollett K, Spiers HJ, Maguire EA. Talent in the taxi: a model system for exploring expertise. *Philos Trans R Soc Lond B Biol Sci* 2009;**364**:1407–16.
34. Maguire EA, Gadian DG, Johnsrude IS, Good CD, Ashburner J, Frackowiak RS, et al. Navigation-related structural change in the hippocampi of taxi drivers. *Proc Natl Acad Sci USA* 2000;**97**:4398–403.
35. Dror I. A novel approach to minimize error in the medical domain: cognitive neuroscientific insights into training. *Med Teach* 2011;**33**:34–8.
36. Dror I, Schmidt P, O'Connor L. A cognitive perspective on technology enhanced learning in medical training: great opportunities, pitfalls and challenges. *Med Teach* 2011;**33**: 291–6.
37. Bengtsson SL, Nagy Z, Skare S, Forsman L, Forssberg H, Ullen F. Extensive piano practicing has regionally specific effects on white matter development. *Nat Neurosci* 2005; **8**:1148–50.
38. Willard FH, Jerome JA, Elkiss ML. Touch. In: Chila A, editor. *Foundations for osteopathic medicine*. Baltimore: Lippincott Williams & Wilkins; 2010. p. 221–7.
39. Rao G, Kanter SL. Physician numeracy as the basis for an evidence-based medicine curriculum. *Acad Med* 2010;**85**: 1794–9.
40. Kassirer JP. Teaching clinical reasoning: case-based and coached. *Acad Med* 2010;**85**:1118–24.
41. da Fonseca V. *Cognicao e aprendizagem*. Lisboa: Ancora Editora; 2001.
42. Vygotsky LS. *Mind and society: the development of higher psychological processes*. Cambridge, MA: Harvard University Press; 1978.
43. Baillie S, Crossan A, Brewster S, Mellor D, Reid S. Validation of a bovine rectal palpation simulator for training veterinary students. *Stud Health Technol Inform* 2005; **111**:33–6.
44. Baillie S, Crossan A, Brewster SA, May SA, Mellor DJ. Evaluating an automated haptic simulator designed for veterinary students to learn bovine rectal palpation. *Simul Health* 2010;**5**:261–6.
45. Howell JN, Conatser RR, Williams 2nd RL, Burns JM, Eland DC. Palpatory diagnosis training on the virtual haptic back: performance improvement and user evaluations. *J Am Osteopath Assoc* 2008;**108**:29–36.
46. Howell JN, Conatser RR, Williams 2nd RL, Burns JM, Eland DC. The virtual haptic back: a simulation for training in palpatory diagnosis. *BMC Med Educ* 2008;**8**:14.
47. Baillie S, Forrest N, Kinniso T. The core skills trainer: a set of haptic games for practicing key clinical skills. In: Astrid ML, et al., editors. *Haptics: generating and perceiving tangible sensations. Lecture notes on computer science (LNCS). Part II*. Heidelberg: Springer; 2010. p. 371–6.
48. Fernandez R, Dror IE, Smith C. Spatial abilities of expert clinical anatomists: comparison of abilities between novices, intermediates, and experts in anatomy. *Anat Sci Educ* 2011;**4**:1–8.
49. Sommerfeld P, Kaider A, Klein P. Inter- and intraexaminer reliability in palpation of the 'primary respiratory mechanism' within the 'cranial concept'. *Man Ther* 2004;**9**:22–9.
50. Parsons J, Marcer N. *Osteopathy: models for diagnosis, treatment and practice*. Edinburgh: Elsevier, Churchill Livingstone; 2005.
51. Gallace A, Spence C. The cognitive and neural correlates of tactile memory. *Psychol Bull* 2009;**135**:380–406.
52. Norman G. Dual processing and diagnostic errors. *Adv Health Sci Educ Theor Pract* 2009;**14**:37–49.
53. Boshuizen HP. Does practice make perfect? In: Boshuizen HP, Bromme R, Gruber H, editors. *Professional learning: gaps and transitions on the way from novice to expert*. Dordrecht: Kluwer Academic Publishers; 2004. p. 73–95.

Available online at www.sciencedirect.com
SciVerse ScienceDirect

Please cite this article in press as: Esteves JE, Spence C, Developing competence in diagnostic palpation: Perspectives from neuroscience and education, International Journal of Osteopathic Medicine (2013), http://dx.doi.org/10.1016/j.ijosm.2013.07.001