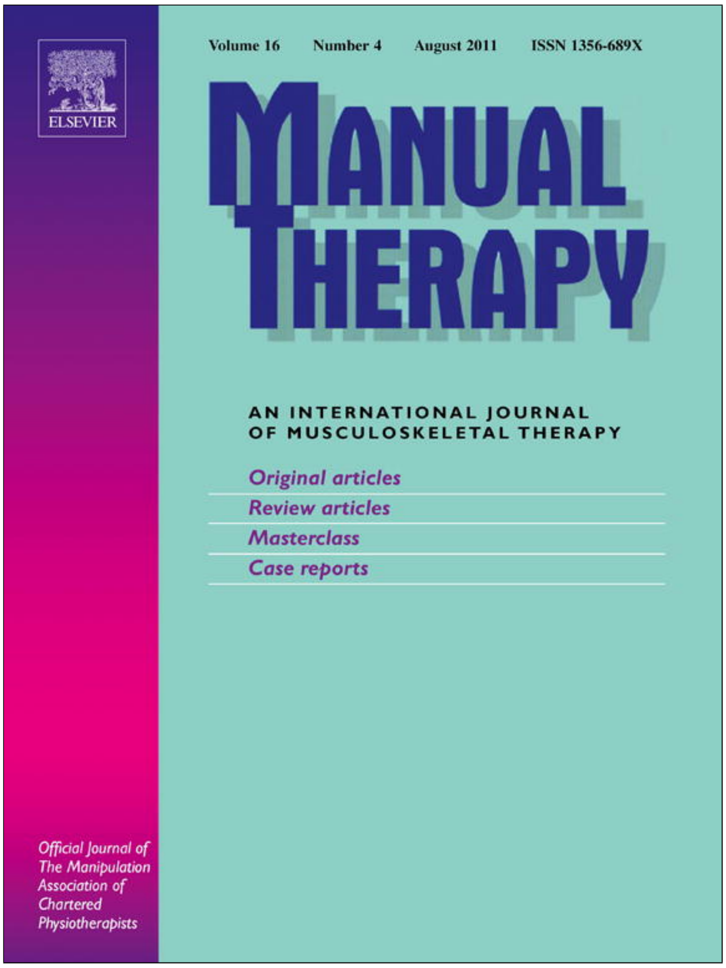
Volume 16 Number 4 August 2011 ISSN 1356-689X
ELSEVIER
MANUAL THERAPY
AN INTERNATIONAL JOURNAL OF MUSCULOSKELETAL THERAPY
Original articles
Review articles
Masterclass
Case reports
Official Journal of The Manipulation Association of Chartered Physiotherapists

Manual Therapy 16 (2011) 327–331

Contents lists available at ScienceDirect

Manual Therapy

journal homepage: www.elsevier.com/math

Original article

The intermediate effect in clinical case recall is present in musculoskeletal physiotherapy

Fernand Gobet*, James L. Borg

Centre for the Study of Expertise, School of Social Sciences, Brunel University, Uxbridge, Middlesex UB8 3PH, UK

ARTICLE INFO

Article history:
Received 29 May 2010
Received in revised form
25 November 2010
Accepted 13 December 2010

Keywords:
Elite performance
Musculoskeletal therapy
Psychology
Sports physiotherapy

ABSTRACT

Previous research into medical expertise has shown that expert physicians perform significantly better than non-experts when providing a diagnosis for a clinical case. By contrast, when asked to recall the details of the case, individuals of intermediate level of expertise (typically, final-year students) obtain better results than novices and experienced physicians, a phenomenon called the "intermediate effect". However, this effect has not been documented outside of internal medicine and dentistry. The aim of this paper was to investigate the possibility that the intermediate effect in clinical case recall exists in musculoskeletal physiotherapy. 40 participants (sport science students, musculoskeletal physiotherapy students and expert musculoskeletal physiotherapists) were assigned to four groups based upon their experience in musculoskeletal physiotherapy (control group with no experience, novices, intermediates and experts). Participants were instructed to read a case study, provide a diagnosis, justify this diagnosis, and recall the case study. It was found that the quality of diagnosis and the number of high-level inferences increased with expertise. By contrast, recall performance followed an inverted U-curve, with the best recall being obtained by intermediates. Thus, the intermediate effect is present in musculoskeletal physiotherapy, despite clear differences in the way medicine and musculoskeletal physiotherapy are taught.

1. Introduction

Considerable research has been carried out in recent decades to understand expert behaviour. The classic research of De Groot (1978), Simon and Chase (1973) and others has shown that experts perform better not only in decision-making tasks, but also in memory recall tasks, thus showing that they can encode domain-specific information rapidly. The standard explanation for these results has been that experts learn, through practice, a large number of perceptual patterns ("chunks") that allow them to rapidly identify the key features of a problem situation. Chunks are linked to information about potential solutions, which explains why experts make better decisions. Chunks also consist of perceptual information, which can be placed in short-term memory (STM). Experts do not have a larger STM than non-experts: individuals of varying skill have the same limitations. However, experts have acquired more and larger chunks and this explains that they recall more information in recall tasks. More recent research has also established that experts develop schema-like structures, called templates, which enable them to encode information rapidly in long-term memory (Gobet and Simon, 1996, 2000).

Of particular practical and theoretical interest has been the research on medical expertise (e.g. Patel and Groen, 1986; Boshuizen and Schmidt, 1992). Consistent with research in other domains, experts in medicine perform better in a decision task (typically a diagnosis task) than less expert individuals. However, contrasting with results in nearly all domains of expertise, performance in a recall task does not show a linear increase with expertise. Rather, individuals with an intermediate level of expertise outperform both novices and individuals with considerable expertise (Muzzin et al., 1983; Claessen and Boshuizen, 1985; Schmidt and Boshuizen, 1993; Rikers et al., 2000). This counterintuitive result, which can be described as an inverted performance U-curve as a function of expertise level, has been called the *intermediate effect*, and has important theoretical implications (Schmidt and Rikers, 2007), because it challenges theories that posit expertise as solely an accumulation of knowledge.

The standard explanation for the intermediate effect (proposed by Schmidt and Boshuizen, 1993) is predicated on the encapsulation of knowledge. It is proposed that medical students first acquire biomedical knowledge (knowledge about anatomy, physiology, biochemistry, pathology and pathophysiology) during their study.

* Corresponding author. Tel.: +44 1895 265484; fax: +44 1895 237573.
E-mail address: fernand.gobet@brunel.ac.uk (F. Gobet).

1356-689X/$ – see front matter
doi:10.1016/j.math.2010.12.003

Only after about four years of theoretical training, and with years of practice in a particular field, do they develop clinical knowledge, which relates to how pathologies manifest themselves in patients. Following medical students' exposure to patients during clinical training, biomedical knowledge becomes progressively re-structured and encapsulated under a limited number of clinically relevant concepts, leading ultimately to script formation. Scripts are narrative structures that contain, as a direct result of encapsulation, relatively little knowledge about pathophysiological causes but that provide a large amount of clinically relevant information about symptoms, complaints and the factors likely to lead to the disease. These concepts and scripts have the same explanatory power as elaborate biomedical explanations, but can be retrieved and processed more quickly. This process of encapsulation requires considerable periods of time interacting with patients (Boshuizen and Schmidt, 1992).

Thus, experts differ not only with respect to the proportion of biomedical and clinical knowledge, but their knowledge base is also characterised by qualitative differences: concepts become subsumed ("encapsulated") under higher-level concepts. That is, experts do not process symptoms and related information as disconnected material, but as integrated wholes that can be summarised by an encapsulated concept. In a recall task, they would remember the encapsulated concept and not the more detailed information that has been subsumed under the concept.

According to Schmidt and Boshuizen (Boshuizen and Schmidt, 1992; Rikers et al., 2002), biomedical knowledge is progressively integrated and encapsulated into clinical knowledge. Experts can rely on their clinical knowledge for making rapid decisions, but can also use biomedical knowledge to justify their diagnosis, if asked to do so, or to solve complex problems for which clinical knowledge is not sufficient. Thus, when diagnosing routine cases, clinical knowledge, which is mostly encapsulated, allows expert physicians to skip intermediate steps and make shortcuts. Because they use these shortcuts, and thus less biomedical knowledge, expert physicians encode relatively little information about the details of the case at hand. By contrast, intermediate individuals lack clinical knowledge due to their lack of exposure to clinical practice, and thus must use their biomedical knowledge, which contains few encapsulated concepts. When doing this, they must pay more attention to the details of the case study, and thus encode more information in long-term memory (LTM). As a consequence, they perform well in the recall task. Another supported prediction of the theory is that the intermediate effect disappears when the time to process the case study is strictly limited (e.g. to 30 s), as intermediate individuals do not have enough time to process and encode the information (van de Wiel et al., 1998). For example, it has been proposed that it takes about 10 s to encode one chunk of information in LTM (Simon, 1974).

The pioneering research of Schmidt and colleagues has uncovered important and interesting phenomena. However, it also suffers from several limitations. First, as in nearly all studies into expertise, participants are not randomly allocated to skill levels. Given this quasi-experimental design, inferences about causality must be cautious. Second, in these experiments, the level of expertise is defined as the number of years in the field. This is a weak definition. For example, it is known from research on chess, which uses a reliable and quantitative measure of skill (Elo rating), that the correlation between expertise level and the number of years spent in the field is weak (Gobet and Campitelli, 2007). Third, and related to the second point, age is a confounding factor in these experiments, in that experts are always older than medical students. Fourth, these experiments have typically used only few problems or even one problem (in studies where recall was incidental) per participant, which makes it impossible to compute reliability in performance. Fifth, exposure time is much longer than in other fields of expertise (e.g. games and sports) because the case studies have to be read. This makes the comparison between fields somewhat difficult. Sixth, these experiments have tended to use the same case studies, which limits the generalisability of the results. Finally, studies into the role of encapsulation of knowledge in the area of medical expertise have been carried out only on one subset of medicine, focusing on internal medicine (e.g. cardiology, pulmonology; Schmidt and Boshuizen, 1993; van de Wiel et al., 1998; Rikers et al., 2000) and dental medicine (Eberhard et al., 2009). The first five limitations are very difficult to avoid, given the necessity of using experts and the nature of the task. However, the sixth and seventh limitations can be ameliorated with new research. The current study aims to add the much needed study of a new domain.

Specifically, it is unknown whether the intermediate effect phenomenon is present with musculoskeletal physiotherapists, and whether musculoskeletal physiotherapists organise their knowledge as proposed by the encapsulated knowledge theory. Although it is a health care profession, musculoskeletal physiotherapy is not strictly speaking a medical discipline, and the training of musculoskeletal physiotherapists differs considerably from that of physicians. In particular, the former get exposed to clinical cases earlier than the latter. At the same time, diagnostic reasoning – which will be investigated in this study – is important in both fields. Hence, establishing whether the intermediate effect occurs with musculoskeletal physiotherapists is of considerable theoretical and practical interest, and would in particular help establish the generalisability of the knowledge encapsulation hypothesis.

Thus, the following experiment aimed to establish whether, in musculoskeletal physiotherapy (a) diagnostic accuracy correlates with expertise level; (b) the amount of recall from a case study is higher in intermediates than novices and experts, thus producing an inverted U-curve; and (c) encapsulated knowledge, as measured by the number of high-level inferences, is greater in experts than non-experts, thus correlating with levels of expertise. The last point is important, as it is necessary to establish that the intermediate effect does not occur because experts lack biomedical knowledge.

2. Method

2.1. Design

A quasi-experimental between-subject design was used. Expertise level was the independent variable, and quality of diagnosis, recall performance and number of high-level inferences used in the diagnosis were the dependent variables. These dependent variables have been used in previous research on the intermediate effect in memory recall, and have led to robust and replicable effect sizes (e.g. Cohen's f was 0.61 for recall performance in Rikers et al., 2000). Power analysis indicated that a four-group design with $\alpha = 0.05$ would have a statistical power of 0.88 with 10 participants in each group. Note that this study had a statistical power higher than the 0.80 recommended by Cohen (1992).

2.2. Participants

A convenience sample was used in this study and forty participants took part. They were arranged into 4 groups of ten participants each: (a) undergraduate sports science students at a UK university, who were acting as a control group; sports science students were chosen because they were expected to be familiar with sport injuries and have knowledge of anatomy, but were not expected to have any experience in making diagnoses and prognoses; (b) first-year physiotherapy students in the same University (novice group); (c) final-year physiotherapy students at the same University (intermediate group); and (d) expert musculoskeletal physiotherapists (expert group). The expert musculoskeletal physiotherapists had at least 5 years of experience in their field, which has been proposed as the minimum number of years of full-time practice to have expert status in nursing (Benner, 1984). Together with 3–4 years of study in the experts, this also insured that the minimal amount of practice and study was close to 10 years, a number proposed by several authors as typical for top experts (Simon and Chase, 1973; Ericsson and Charness, 1994). The practice of the experts involved treating patients on a daily basis and dealing with a wide array of injuries, ranging from the routine to the more complex ones. Students were recruited by advertisement on the campus, and musculoskeletal physiotherapists were recruited using professional contacts. The study was approved by the ethical committee of the School of Social Sciences at Brunel University. The principles outlined in the Declaration of Helsinki were followed, and informed consent of participants was obtained.

2.3. Materials

A written case study described a hamstring muscle injury. It included a description of the manner in which the injury took place, the symptoms, the situation in which it occurred, and the reactions of the injured patient (The complete case text can be found in Appendix A). The case was based on an actual patient who suffered a hamstring injury, and who received the necessary diagnosis and treatment. A Dictaphone was used to record the participants' diagnosis, explanations and recall. An independent professional musculoskeletal physiotherapist checked the case description to ensure that it was suitable and contained enough information for a diagnosis to be made. Having an independent expert checking the experimental stimuli (here, the case description) is common practice in expertise research (Bilalić et al., 2009).

2.4. Procedure

Participants first read the case study. They were then asked to provide a diagnosis as accurately as they could. They also had to justify the diagnosis, give a recommendation for immediate treatment and provide a suitable prognosis. Participants were then asked to recall as much as possible about the case in a separate memory recall test. They carried out the experiment individually, and with no previous knowledge of the case study or other participants' participation in the study. They had as much time as required for each phase of the experiment. All speech was recorded by a voice activated Dictaphone.

2.5. Data scoring and analysis

Diagnostic accuracy was estimated using a seven-point scale (from 0 [totally incorrect] to 6 [totally correct]). Data scoring and analysis followed the procedure used by Rikers et al. (2002). An independent musculoskeletal physiotherapist oversaw the scoring of the diagnoses to ensure they were correct. The use of an independent expert to help score diagnoses is standard practice in medical expertise research (Rikers et al., 2000).

The amount of biomedical knowledge was estimated using the number of high-level inferences that were made when participants carried out the diagnosis (A statement such "It's obviously a hamstring injury as he is complaining of a sharp pain in his leg where he is clutching at the back" would be counted as a high-level inference.) This was done using the discourse analysis procedure developed by Kintsch (1974, 1988), which is based on the analysis of propositions. The analysis involved the separation of the verbal protocol into individual propositions. The analysis of high-level inferences was used to determine whether or not encapsulated knowledge was used at all. The presence of high-level inferences indicates that the participant is using segmented knowledge encapsulations. Low-level inferences, which are taken directly from the case description, do not indicate that encapsulated knowledge has been used. Discourse analysis was also used to examine the material remembered by the participants in the recall task. This was done by tallying of the number of propositions recalled from the case description.

Although the assumptions of normality and homogeneity of variance were violated in some cases, it was decided to use one-way analysis of variance (ANOVA) as it is known that this procedure is very robust (Howell, 1987), in particular with equal sample sizes as it is the case in this study. The level of significance was set to $p \leq 0.05$ throughout. Post-hoc tests were carried out with Tukey HSD. The analyses were carried out with SPSS (version 15).

3. Results

3.1. Diagnostic accuracy

Fig. 1 shows the mean scores as a function of expertise level. A one-way ANOVA revealed a skill effect, F (3, 36) = 38.47, mean square error (MSE) = 37.29, $p < 0.05$, partial $\eta^2 = 0.76$. Tukey HSD post-hoc tests revealed that the control group performed always statistically significantly worse than the other groups (all $p < 0.05$) and that the expert group also performed statistically significantly better than the novice group ($p < 0.05$) and the intermediate group ($p < 0.05$).

Furthermore, all musculoskeletal physiotherapists in the expert group scored as accurately as possible (maximum score = 6), providing not only an accurate diagnosis and but also an accompanying accurate prognosis. By contrast, only 3 intermediate participants scored a maximum of 6, with not a single participant scoring higher than a 5 in either the novice group or the control group. These results suggest that the chosen case study is ecologically valid, as it was able to discriminate between individuals of different expertise levels.

3.2. Recall task

Fig. 2 displays the mean recall scores as a function of expertise level. A one-way ANOVA indicated that the groups performed

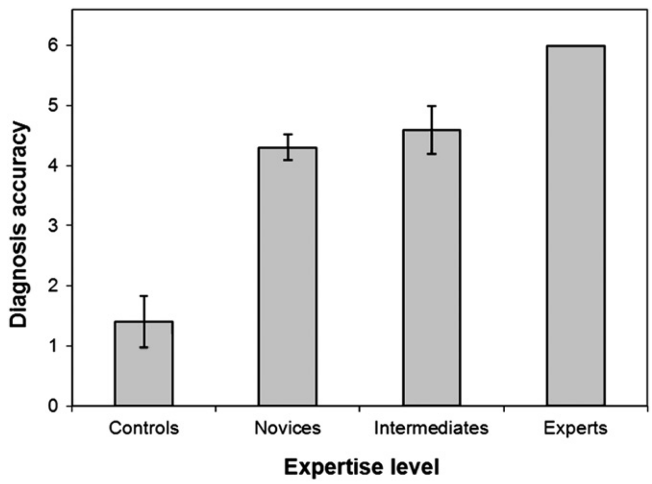

Fig. 1. Mean diagnostic accuracy as a function of skill level. Error bars indicate standard errors of the mean.

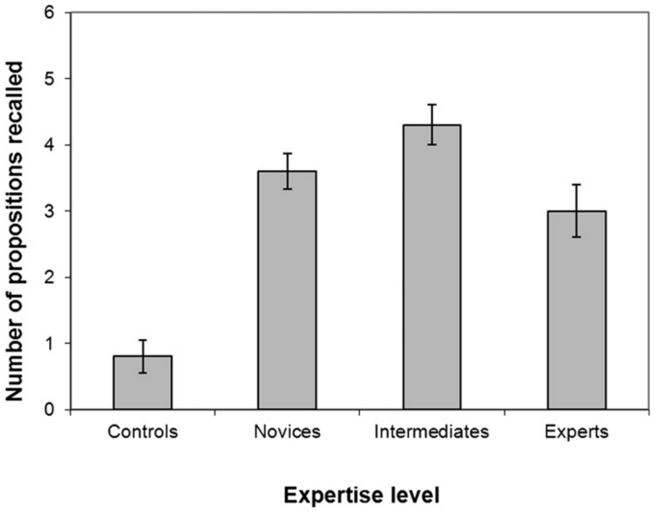

Fig. 2. Mean number of propositions correctly recalled as a function of skill level. Error bars indicate standard errors of the mean.

statistically differently, $F(3, 36) = 24.17$, $MSE = 22.89$, $p < 0.05$, partial $\eta^2 = 0.67$. The presence of an inverted U-curve was confirmed by a trend analysis, showing a statistically significant quadratic component, $F(1, 36) = 44.37$, $MSE = 42.02$, $p < 0.05$. Tukey HSD post-hoc tests revealed that the control group statistically significantly obtained lower performances than the other three groups (all $p < 0.05$), and, crucially, that the intermediate group (mean = 4.3) performed reliably better than the expert group (mean = 3.0; $p < 0.05$).

3.3. High-level inferences

High-level inferences were examined as an indication for the presence of knowledge encapsulation. Fig. 3 displays the mean scores as a function of skill level. A one-way ANOVA indicated that there was an overall skill effect, $F(3, 36) = 21.51$, $MSE = 48.87$, $p < 0.05$, partial $\eta^2 = 0.64$. Tukey HSD post-hoc tests showed that the control group had reliably fewer higher inferences that all the other skill levels (all $p < 0.05$), and that the expert musculoskeletal physiotherapists produced more high-level inferences than the novices ($p < 0.05$). However, no statistically reliable difference was found between experts and intermediates.

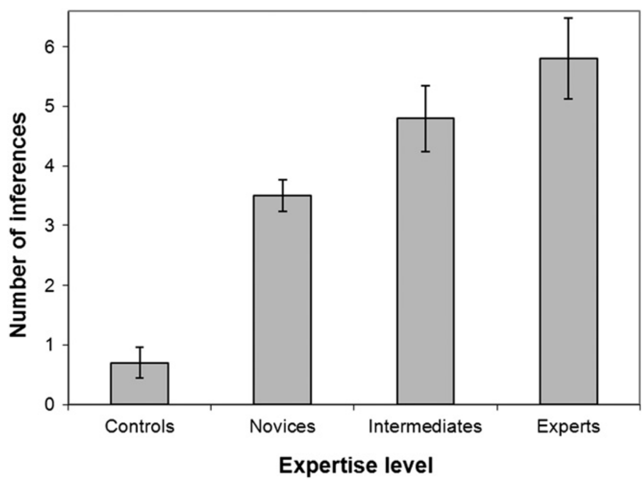

Fig. 3. Mean number of high-level inferences during diagnosis as a function of skill level. Error bars indicate standard errors of the mean.

4. Discussion

In line with previous research on medical expertise, the results showed that diagnosis accuracy correlated with the level of expertise. Recall performance was found to follow an inverted U-curve – the intermediate effect. Just like in earlier experiments, the recall task provided a very strong experimental effect: Cohen's f was 1.36, as compared for example to 0.61 in Rikers et al. (2000), which is already considered a large effect size (Cohen, 1992). Finally, an analysis of the statements in the diagnosis showed that the use of high-level inferences increased with expertise. Thus, the intermediates recalled a larger number of propositions from the case study, using their biomedical knowledge to process the information contained in the text, whereas the experts produced a clinical case representation with the use of encapsulated knowledge. The results support the theory proposed by Schmidt and colleagues that intermediates rely mostly upon biomedical knowledge and the specific text propositions, while experts use clinical case representations and encapsulated knowledge, thus recalling fewer propositions. Thus, the results indicate that the intermediate effect in memory recall is present in musculoskeletal physiotherapy, and that the mechanism proposed by Schmidt and colleagues is likely to be at work here as well.

The diagnostic accuracy scores show that the experts were very accurate indeed. This suggests not only that experts would be successful with real-life cases resembling the current case study, but also that they had dealt with such injuries on a regular basis. This apparent ceiling effect may not so much reflect the simplicity of the case as the sheer rate at which they had seen resembling injuries in their practice. Frequent occurrences would provide a suitable environment for the development of schematic knowledge expert skills (Gobet, 2005).

The fact that each expert participant had at least five years of practice as a working professional (in addition to the years spent studying) suggests that the diagnosis of injury is almost second nature to the experienced professional. Although the high diagnosis accuracy is striking, it is the manner in which this accuracy has been reached that most captures the attention. Expert musculoskeletal physiotherapists' performance resembled that of other medical professionals in previous research (Rikers et al., 2002), in that they skipped intermediary steps and used shortcuts whilst making a diagnosis. This supports the theory of encapsulated knowledge, in that experts when diagnosing a patient do not only rely upon biomedical knowledge and propositions from the case study, preferring a representation based on snippets of clinical knowledge. The study supports the notion that such capabilities develop with experience.

In line with previous experiments (e.g. Claessen and Boshuizen, 1985), no time limit was imposed for reading the case study, making a diagnosis, and recalling information. This had the advantage of keeping the ecological validity of the task high. An avenue for future research is to manipulate the reading time of the case, as was done for example by Schmidt and Boshuizen (1993) with medical expertise. Schmidt and Boshuizen's rationale was that time is needed for searching, retrieving and processing the appropriate pathophysiological knowledge. Thus, decreasing processing time will decrease the extent to which intermediates produce pathophysiological explanations. By contrast, a reduction in processing time will not affect the amount of explanation provided by experts, because their knowledge, being encapsulated, can be more easily retrieved and processed. As predicted, Schmidt and Boshuizen found that decreasing time affected intermediates but not experts. It would be interesting to investigate whether the same effect is found with musculoskeletal physiotherapists.

It is somewhat surprising that the intermediate effect was found, in spite of the fact that the theoretical training of musculoskeletal physiotherapists is considerably shorter than that of the medical students typically studied in the literature, and that they see clinical cases more rapidly. For example, the BSc (Hons) physiotherapy programme at the University in which the novices and intermediates of this study were enrolled requires clinical placements in their second year already. By contrast, medical students in the Netherlands, who constitute a substantial subset of the medical students studied in the literature, typically spend four years acquiring biomedical knowledge and rarely deal with clinical cases directly during this time (Eberhard et al., 2009).

Several limitations of this study should be noted, which means that the results should be interpreted with caution. Echoing the limitations in Schmidt and colleagues' studies discussed in the introduction, the design was quasi-experimental, expertise was defined as the number of years spent in the field, age was a possible confounding variable, and the case study had to be read, which hampers comparison with results from other fields of expertise. In addition, only one single clinical case was used. This was unavoidable, because it was important that participants were not aware that their memory for the case would be tested, or else they could have developed strategies specifically aimed at memorising details of the case. Finally, the clinical case was fairly simple, much simpler that the cases typically used in the study of medical expertise. The observed ceiling effect for the diagnosis scores with experts, and to a lesser degree intermediates, might have attenuated skill effects in diagnosis quality.

5. Conclusion

This study has shown that the intermediate effect in memory recall occurs with musculoskeletal physiotherapists, corroborating previous results in medical expertise. While experts provided better diagnoses and used more high-level inferences, they remembered less information in the recall task. Thus, the pattern first identified with internal medicine was found, providing additional support to the theory of knowledge encapsulation. According to the recommendations given by Schmidt and Rikers (2007) for medical education, working with patients early together with learning basic science and actively elaborating patient problems either with a coach or in small groups of peers should facilitate the integration of biomedical and clinical knowledge, and thus encapsulation of knowledge. Although the intermediate participants in the current study (final-year musculoskeletal physiotherapy students) had worked with a variety of patients since the second year of their study, the intermediate effect was observed. This suggests that early and frequent contacts with patients are not the only key factor in developing clinical expertise. Further research will have to find out what these other factors are.

Acknowledgments

We would like to thank all those who took part in this experiment and Dr Costas Karageorghis for his help in the recruitment of participants, his advice about the case study used and his feedback about the analysis of the participants' protocols. Dr Yvan Russell provided useful comments on an earlier version of the manuscript. FG was supported by an ESRC Research Fellowship.

Appendix A. Case study: Andrew the striker

Andrew is a talented young footballer who utilises his natural explosive abilities at the Centre Forward position. He often loses his defenders with his quick off ball movements and frequently confuses defenders and, occasionally, even his own teammates. With the ball at his feet, there are few defenders around who can keep with his speed, especially when he is faced with an open field to run into, a position to which any goalkeeper would be less inclined to oppose. Andrew is 5″9 in height, weighs around 10 stones, and is of a very compact nature. He prefers to play to his left foot. On this occasion, Andrew makes a run into the attacking third in an attempt to infiltrate the opposition's defence by meeting a long ball played from his "right back" teammate, who aims the ball ahead of Andrew. In an attempt to remain onside, Andrew is focused on beating his man to the ball legally. He embraces his natural sprint ability by exploding forwards, breaking free from his marker. As the ball takes a first bounce, Andrew, in full sprint, pulls up abruptly, wincing in pain, and clutching the back of his leg. He collapses to the floor, unable to walk, and requires a medic desperately. He complains about a sharp, stabbing pain in the upper back of his leg, which appears swollen, bruised, and lumpy. Andrew says that he is unable to walk, and requires a stretcher to carry him off the field.

References

Benner P. From novice to expert: excellence and power in clinical nursing practice. Menlo Park, CA: Addison-Wesley; 1984.
Bilalić M, McLeod P, Gobet F. Specialization effect and its influence on memory and problem solving in expert chess players. Cognitive Science 2009;33:1117–43.
Boshuizen HPA, Schmidt HG. On the role of biomedical knowledge in clinical reasoning by experts, intermediates and novices. Cognitive Science 1992;16(2):153–84.
Claessen HFA, Boshuizen HPA. Recall of medical information by students and doctors. Medical Education 1985;19:61–7.
Cohen J. A power primer. Psychological Bulletin 1992;112:155–9.
De Groot AD. Thought and choice in chess (first Dutch edition in 1946). The Hague: Mouton Publishers; 1978.
Eberhard J, Klomp HJ, Foge M, Hedderich J, Schmidt HG. The intermediate effect and the diagnostic accuracy in clinical case recall of students and experts in dental medicine. European Journal of Dental Education 2009;13(3):128–34.
Ericsson KA, Charness N. Expert performance: its structure and acquisition. American Psychologist 1994;49:725–47.
Gobet F. Chunking models of expertise: implications for education. Applied Cognitive Psychology 2005;19(2):183–204.
Gobet F, Campitelli G. The role of domain-specific practice, handedness and starting age in chess. Developmental Psychology 2007;43:159–72.
Gobet F, Simon HA. Templates in chess memory: a mechanism for recalling several boards. Cognitive Psychology 1996;31:1–40.
Gobet F, Simon HA. Five seconds or sixty? Presentation time in expert memory. Cognitive Science 2000;24:651–82.
Howell CH. Statistical methods for psychology. Boston: PWS-KENT; 1987.
Kintsch W. The representation of meaning in memory. Hillsdale, NJ: Lawrence Erlbaum Associates; 1974.
Kintsch W. The role of discourse comprehension: a construction-integration model. Psychological Review 1988;95:163–82.
Muzzin LJ, Norman GR, Feightner JW, Tugwell P. Expertise in recall of clinical protocols in two specialty areas. In: Proceedings of the 22nd conference on research in medical education. Washington, DC: American Association of Medical Colleges (AAMC); 1983. p. 122–8.
Patel VL, Groen GJ. Knowledge based solution strategies in medical reasoning. Cognitive Science 1986;10:91–116.
Rikers RMJP, Schmidt HG, Boshuizen HPA. Knowledge encapsulation and the intermediate effect. Contemporary Educational Psychology 2000;25:150–66.
Rikers RMJP, Schmidt HG, Boshuizen HPA. On the constraints of encapsulated knowledge: clinical case representations by medical experts and subexperts. Cognition and Instruction 2002;20:27–45.
Schmidt HG, Boshuizen HPA. On the origin of intermediate effects in clinical case recall. Memory & Cognition 1993;21:338–51.
Schmidt HG, Rikers R. How expertise develops in medicine: knowledge encapsulation and illness script formation. Medical Education 2007;41(12):1133–9.
Simon HA. How big is a chunk? Science 1974;183:482–8.
Simon HA, Chase WG. Skill in chess. American Scientist 1973;61:393–403.
van de Wiel MWJ, Schmidt HG, Boshuizen HPA. A failure to reproduce the intermediate effect in clinical case recall. Academic Medicine 1998;73(8):894–900.