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Medical students' biomedical and clinical knowledge: Combining longitudinal design, eye tracking and comparison with residents' performance

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ABSTRACT

This study combines longitudinal and individual process-level analyses to investigate medical students' biomedical knowledge and how they generate a diagnosis for a patient case text. The diagnostic processes were investigated using the eye-tracking method, and students' processes were compared with those of residents. The results showed that students differed in their diagnostic performance in the beginning of the clinical phase. Of the students who had biomedical misconceptions in the preclinical phase, 69% ended up with an incorrect diagnosis, while 60% of students with accurate biomedical knowledge made a correct diagnosis. The processing of a patient case text was faster among better-achieving students and residents. Furthermore, residents' illness-script activation could be seen from their eye-movement data as a relatively longer reading time regarding the sentence that concerned the enabling condition of the case. Based on the results of the study, pedagogical suggestions are discussed.

1. Introduction

In recent decades, several studies have aimed to understand how medical students acquire a high level of competence on their way to achieving medical expertise (see e.g. Kuipers & Kassirer, 1984; Schmidt & Boshuizen, 1993; Schmidt & Rikers, 2007). There is a general consensus that basic science or biomedical knowledge provides a foundation for clinical knowledge (Kaufman, Keselman, & Patel, 2008; Woods, 2007), and recent studies have shown that students with better biomedical knowledge succeed better in clinical reasoning tasks (see e.g. Ahopelto, Mikkilä-Erdmann, Olkinuora & Kääpä, 2011; Nivala, Lehtinen, Helle, Kronqvist, Paranko & Säljö, 2013). However, less is known about how the level of biomedical knowledge relates to diagnostic accuracy in the early clinical phase of medical studies. In this study, the development of medical students' biomedical knowledge concerning one of the most essential but complex systems — the central cardiovascular system (CCVS) — is followed up twice during their preclinical phase and compared to students' success in a clinical reasoning task at the beginning of the clinical phase.

Previous studies have provided interesting insights into novices' and experts' diagnosis of written patient cases (see e.g. Boshuizen, van de Wiel, & Schmidt, 2012), but with a few exceptions (e.g. Vilppu, Mikkilä-Erdmann, Södervik & Österholm-Matikainen, 2017), such research has not focussed on the processes by which participants use the case description text while coming to a diagnosis. In this study, students' processing of a patient case text concerning a pulmonary embolus — in which understanding of the content is expected to suggest biomedical knowledge of the CCVS —is studied via eye movements, interviews and written tasks to study whether there are differences among students in their processes. Eye tracking offers a suitable method to study diagnostic processing, as eye movements indicate cognitive processing during the task (to read more about the widely accepted eye-mind hypothesis, see Just & Carpenter, 1980). To evaluate students' diagnostic processes, their processing was compared with that of medical residents, who had completed their six-year basic medical degree studies and already begun their specialisation training.

Different theories have been developed concerning how medical students construct a coherent entity of biomedical and clinical knowledge during their studies, thereby gradually learning to solve complex clinical problems (see e.g. Boshuizen & Schmidt, 1992;

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Feltovich & Barrows, 1984; Kuipers & Kassirer, 1984; Patel, Evans, & Groen, 1989; Schmidt & Boshuizen, 1993; de Bruin, Schmidt, & Rikers, 2005). Patel et al. (1989) argued that biomedical knowledge and clinical knowledge can be considered worlds apart, meaning that clinical knowledge and biomedical concepts construct separate knowledge structures; hence, biomedical knowledge is involved in clinical reasoning only in the sense that it provides coherence when solving exceptionally complex patient cases. However, at present, there is more empirical evidence supporting another perspective, where biomedical and clinical knowledge need to be integrated (i.e. encapsulated) for medical expertise to be achieved (Boshuizen et al., 2012). According to encapsulation theory, successful medical education and later expertise development cause biomedical knowledge to become constructed into knowledge structures that comprise concepts under which many lower-level details and interrelations of information are organised (see Schmidt & Boshuizen, 1993; Schmidt & Rikers, 2007; Van de Wiel, Boshuizen, & Schmidt, 2000).

In the preclinical phase, which takes approximately the first 2.5 years of medical studies, students' main aim is to build an extensive understanding of basic scientific knowledge, such as the anatomy and physiology of the human body. However, previous research has shown that the learning of biomedical contents poses challenges for medical students and often suggests the abandoning of certain misconceptions (see e.g. Chi, 2005; Mikkilä-Erdmann, Södervik, Vilppu, Kääpä & Olkinuora, 2012). In addition, from the very beginning of medical studies, students begin to acquire some practical experience, first via observing physicians' work in healthcare centres and later via real patient encounters. As students begin to use their biomedical knowledge in the clinical context, their biomedical knowledge starts to integrate with clinical experience and they begin to reorganise *illness scripts* (see e.g. Charlin, Boshuizen, Custers, & Feltovich, 2007; Feltovich & Barrows, 1984; Schmidt & Rikers, 2007; de Bruin et al., 2005). An illness script (Feltovich & Barrows, 1984) is an integrated model of medical abnormalities, which specifies illness in terms of enabling conditions serving as background factors to influence the probability that an individual has contracted a disease (e.g. travelling to a malaria-endemic area) and possibly contribute to the fault, that is, the pathophysiological malfunctioning constituting the biomedical core of a disease (e.g. an enlarged spleen). This fault may give rise to certain consequences that are typically complaints, signs and symptoms (e.g. a high fever every other day) (Boshuizen et al., 2012; Custers, Boshuizen, & Schmidt, 1998).

In real settings, physicians must address extremely complex and multifaceted patient cases that are influenced by the patients' background information, personal sensations, symptoms and findings. Therefore, the physician's challenge is to differentiate substance (e.g. the relevant symptoms) from competing noise (e.g. irrelevant symptoms) in each case. Illness scripts are thought to help physicians to find patterns of diseases, filter out irrelevant information, rule out several diseases and construct working diagnoses (Monajemi, Schmidt, & Rikers, 2012). Previous studies have shown that because medical students are often unable to recognise these patterns, they may fail to make the correct diagnosis (Monajemi et al., 2012). Further, a characteristic of more experienced physicians is that they seem to make better use of the enabling conditions of a specific case compared to novices (Schmidt & Rikers, 2007). This means that an experienced doctor recognises predisposing factors better than novices; thus, for medical experts, enabling factors could be efficient promoters of illness-script activation.

1.1. Research questions

The research questions in this study are as follows:

1. *Are there differences among the participants in their diagnostic accuracy and do they differ at the stage of reading in which they find correct diagnosis of a patient case text?* It is suggested that residents with more clinical experience will be more accurate and efficient in making a diagnosis than students (see e.g. Charlin et al., 2007). However, as diagnostic reasoning is a complex skill, it is also suggested that there would be variation among medical students in their diagnostic accuracy and efficacy.
   1.1. *Do the processing times for a patient case text differ between participants who give a correct versus an incorrect diagnosis?* Following encapsulation theory and the results of previous eye-tracking studies, it is expected that those who diagnose the case correctly will process the case more quickly (e.g. Charlin et al., 2007; Mann, Williams, Ward, & Janelle, 2007; Schmidt & Rikers, 2007).
   1.2. *Do the participants giving a correct versus an incorrect diagnosis differ in their use and processing of different-level sentences of the patient case text?* Based on previous research, it is hypothesised that those who diagnose the case correctly will be more effective in directing their attention to the task-relevant areas of the text and hence, expected to mention more relevant issues in the written answers compared to the less successful participants. Moreover, based on illness-script theory, it is suggested that residents may make more use of sentences that relate to the enabling conditions of the patient case text than medical students (see Schmidt & Rikers, 2007).
2. *Are the level of biomedical knowledge and the occurrence of misconceptions about the CCVS, and medical entrance examination results, related to success in the clinical reasoning task among third-year medical students?* Previous studies have shown that the level of biomedical knowledge is related to the level of clinical reasoning (e.g. Nivala et al., 2013). Since it has been suggested that understanding the pathophysiology of pulmonary embolus requires accurate biomedical knowledge related to the CCVS, we suggest that those students who diagnose the case correctly may have fewer misconceptions and higher scores for their biomedical knowledge of the CCVS.

2. Method

2.1. Participants and design

The participants were native Finnish-speaking students from one Finnish medical school (see Table 1). The students were followed up concerning their biomedical knowledge about the CCVS twice during their initial study years in 2009–2010. The whole class of medical students participated in group study phases 1–2 (more detailed description and results are provided in Ahopelto et al., 2011). However, only those who were involved in the single-case study phase are focussed on in the present study.

A total of 39 third-year students and 13 internal medicine residents from one Finnish university hospital participated in the single-case study phase, which was conducted in spring 2011 for students and spring 2012 for residents. The eye-tracking data were poor for six students; hence, 33 students (24 women) and 13 internal medicine residents (eight women) were included in the study. The participating students represented 27% of the third-year medical student population, with the total size of the cohort being 122. The residents represented the total number of residents