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Competence Assessment for Spinal Anaesthesia

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Abstract. The authors describe a new approach towards assessing skills of medical trainees. Based on experiences from previous projects with (i) applying virtual environments for medical training and (ii) competence assessment and personalisation in technology enhanced learning environments, a system for personalised medical training with virtual environments is built. Thus, the practical training of motor skills is connected with the user-oriented view of personalised computer-based testing and training. The results of this integration will be tested using a haptic device for training spinal anaesthesia.

Keywords: Competence Assessment, Competence-based Knowledge Space Theory, Spinal Anaesthesia, Usability in Ambient Assisted Living and Life Long Learning, Simulations in Medicine.

1 Introduction

The current methods used for training in medical procedural (or technical) skills are inefficient and may jeopardise patient safety as medical trainees are required to practice procedures on patients. The resultant worldwide move towards competence-based training programmes has necessitated the search for valid and reliable competence assessment procedures (CAPs). The challenges in developing such CAPs lie in defining each competence and taking account of the many factors which influence learning and performance of medical procedures. Such determinants include cognitive, motor, communication, and emotional (e.g. fatigue, anxiety, or fear) factors. In other domains, competence-based knowledge space theory (CbKST) has been successfully applied to enhance learning, assess competence and facilitate personalised learning [see, e.g., 1, 2, 3]. The objective of our starting project is to transfer this approach to the medical domain in order to develop a valid, reliable and practical CAP for one medical procedural (and motor) skill, spinal anaesthesia. In order to do so, we will comprehensively describe the competences, generate algorithms necessary to assess individual performance, implement the CAP in a user-friendly, web-based format and test it in simulated and real clinical settings for construct validity and reliability.

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In the following sections, we give short introductions to spinal anaesthesia and to competence-based knowledge space theory. Section 4 finally describes the work approach for the new project.

2 The Spinal Anaesthesia Technique

Regional anaesthesia is a major component of modern anaesthetic practice. It means blocking the nerve supply to an area of the body so the patient cannot feel pain in that region. Many procedures can be performed on patients who are awake, using regional anaesthesia. This may avoid the risk and unpleasantness sometimes associated with general anaesthesia and may provide specific benefits.

The most common type of regional anaesthesia is *spinal anaesthesia*. This involves putting local anaesthetic through a needle near the spinal cord into the fluid, which surrounds it to anaesthetize the lower region of the body (see Fig. 1).

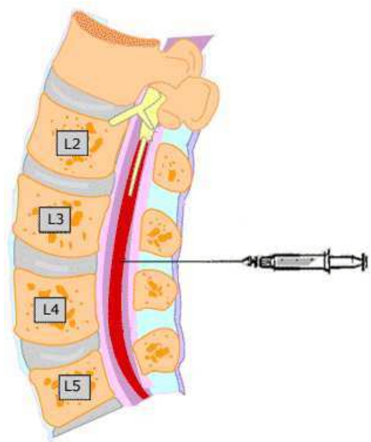

Fig. 1. Spinal anaesthesia

Spinal anaesthesia quickly blocks pain with a small amount of local anaesthetic, it is easy to perform and has the potential to provide excellent operating conditions for surgery on the lower part of the abdomen and legs. The local anaesthetic agents block all types of nerve conduction and prevent pain and may also prevent movement in the area until the block wears off. The effects of different local anaesthetics last for different lengths of time, so the length of the anaesthetic can be tailored to the operation.

Teaching spinal anaesthesia to medical trainees traditionally follows two steps, (i) teaching declarative knowledge, e.g., on anatomy, and (ii) supervised practical training on patients. Due to cost factors and to recent changes in European work laws, the second step of this education has to be strongly reduced. The resulting gap in medical training shall be compensated through computer supported competence assessment and (later on) competence teaching.

The DBMT project (Design Based Medical Training, see http://www.dbmt.eu/] has been developing a haptic device supporting a first-stage practical training in spinal anaesthesia in a virtual environment [4]. Figure 2 shows a photo of the device in its current stage of development. This device allows the trainee to obtain the sensory experience connected of performing spinal anaesthesia without putting patients to the risk that it is applied by practical novices.

Fig. 2. Training device for spinal anaesthesia

3 Competence-based Knowledge Space Theory (CbKST)

Knowledge space theory (KST) was originally developed for the adaptive assessment of knowledge in a behaviouristic paradigm [5, 6]. The research groups around Albert in Heidelberg and Graz extended this approach by connecting the observed behaviour to its underlying competences [7]. These extensions then built the basis for developing approaches for personalised technology enhanced learning [8, 2, 3].

The basic idea underlying KST and CbKST is to structure a domain of knowledge by prerequisite relationships. The key idea is to assign to each competence a set of prerequisite competences, i.e. a set of other competences which have to be acquired first[1]. If we define the *competence state* of a trainee as the subset of competences within the regarded domain of knowledge that this trainee has acquired then the set of possible competence states, the *competence space,* is restricted by the prerequisite relation. The prerequisite relation then provides a good basis for personalised assessment and training of competences thus imitating a private teacher.

For the personalised assessment [6, Chapter 9-11], we start testing a competence of medium difficulty. Depending on the correctness of the trainee's answer, we can draw conclusions not only on the mastery of the actually tested competence. In case of a correct answer, we have also obtained evidence for the mastery of the prerequisites. Vice versa, in case of a wrong answer, we have also obtained evidence for the

[1] In a more advanced approach, the prerequisites of a competence are modelled as a family of prerequisite competence sets, the so-called clauses. Each clause can represent, e.g., a different approach to teach the respective competence or a different path to solve a respective problem.

non-mastery of those competences for which the actually tested competence is a prerequisite. Modelling the trainee's competence state through a likelihood distribution on the set of all possible competence states, each piece of evidence leads to an update of this likelihood distribution. Within the update, the likelihood of states consistent with the observed behaviour is increased while the likelihood of inconsistent states is decreased. Subsequent competences to be tested are selected on the basis of this updated distribution. The assessment procedure selects always competences of medium difficulty to be tested where the difficulty of competences depends on the current likelihood distribution.

Previous experiences and simulations show that this procedure leads to a drastically reduced number of competences to be actually tested [1]. Furthermore, this assessment delivers a non-numeric result, i.e. we do not only know the percentage of competences mastered by the trainee but we also know exactly which competences are mastered and which competencies still need some training.

This leads to the application of the competence space for personalised learning. Based on the non-numerical assessment result one can easily determine which competences need to be trained, and based on the prerequisite relation one can derive in which order the missing competences should be acquired. Thus we avoid frustrating our trainees by trying to teach them competences for which they lack some prerequisites.

The techniques described herein have been applied successfully in several research prototypes [see, e.g., 8, 2], and in the commercial ALEKS system (Assessment and Learning in Knowledge Spaces, see http://www.aleks.com/), a system for the adaptive testing and training of mathematics in and beyond the K12 area.

More recently, CbKST has been applied for assessing learners' competences implicitly, i.e. based on their ongoing actions instead of explicitly posing problems to the learner [9, 10, 11]. Especially the situation in game-based learning bears many similarities to virtual environments for practical medical training.

4 Competence Assessment for Spinal Anaesthesia

The project "Competence Assessment for Spinal Anaesthesia" is a collaborative project involving five partners from four countries. A course is built based on the device and contents developed within the DBMT project. After defining the overall set of competences involved in this course, specific competences are assigned to each element of the course. A training system is implemented in a modular, service oriented architecture using existing parts where possible. Figure 3 shows a sketch of the elements of this system.

The experiences from applying CbKST to game-based learning [10,12] show its high suitability for the non-numeric assessment of competences in complex task solution processes. Observing the trainees every step in the virtual reality training environment, the system cannot only judge whether the spinal anaesthesia would have been applied successfully but it will also determine which competences need more training or are missing at all. In a further development to a full-fledged e-learning system it would also offer appropriate teaching and training material on these competences. In the sequel, the architecture of such a full-fledged e-learning system on spinal anaesthesia is briefly sketched.

The learner communicates through the Web with the core learning system. This learning system channels content of classical nature to the learner while communication to the virtual environment is, of course, to take place directly through the respective devices. Any actions of the learner, e.g. activities in the virtual environment or answers to test problems, are passed on to the assessment module which updates its learner model according to the observed action and to the underlying competences. This learner model is then used by the learning system for selecting new contents and can also be used by the virtual environment for adapting current situations.

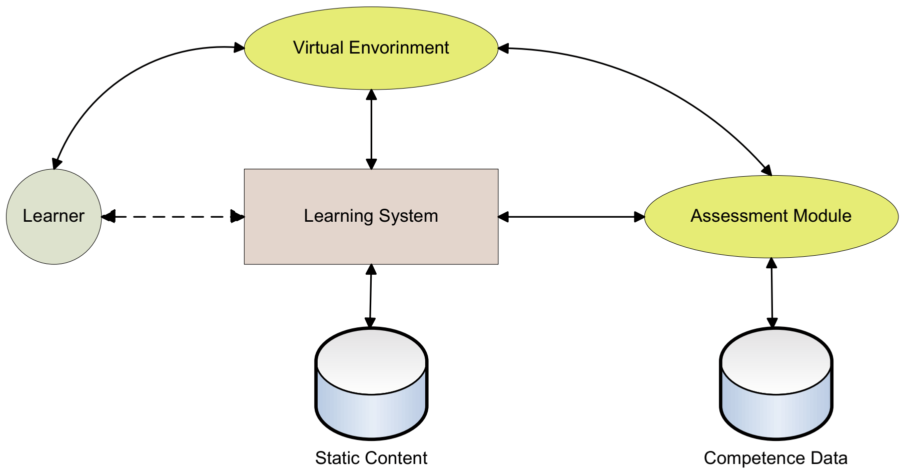

Fig. 3. Architecture of the medical training system

Developing this medical training system involves several aspects of usability and usability research. First, there is, of course, the consideration of results of usability research, on a general level [see, e.g., 13] as well as for the specific area of medical training systems based on virtual reality [14]. A special focus will be on the interplay and integration of the virtual reality and the classical e-learning parts of the system.

A second aspect is the adaptivity of the system which is an ambivalent feature with respect to usability. While adaptivity to the individual user generally is regarded positive, in e-learning it includes some change of the visible content based on the trainee's learning progress leading to possible unwanted confusion. Solving this ambivalence still remains an open challenge for research.

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