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THE APPLICATION OF IMPROVED, STRUCTURED AND INTERACTIVE GROUP LEARNING METHODS IN DIAGNOSTIC RADIOLOGY

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This study provides an example on how it is possible to design environments in a diagnostic radiology department that could meet learning demands implied by the introduction of new imaging technologies. The innovative aspect of the design does not result from the implementation of any specific tool for learning. Instead, advancement is achieved by a novel set-up of existing technologies and an interactive format that allows for focussed discussions between learners with different levels of expertise. Consequently, the study points to what is seen as the underexplored possibilities of tailoring basic and specialist training that meet the new demands given by leading-edge technologies.

INTRODUCTION

One persistent dilemma for education is the struggle to provide up-to-date training tailored for high-end technologies. The ever-increasing pace in which such technologies are implemented means that competences needed for their successful use have to be developed before any formal education programmes exist. Consequently, there is a need for designing workplace-learning environments in which both experienced professionals and novices can develop and improve essential skills(1). The present study investigates an approach adopted in a radiology department, which was aimed at improving the detection of pulmonary nodules arising from the application of a novel medical imaging technology (tomosynthesis)(2). The main purpose of this study was to investigate the suggested approach in terms of the desirable qualities involved in developing more professional modes of image analysis and reasoning among novices in the field.

For many years, modern medicine has been fused with—and is thereby partly dependent on—a vast number of imaging technologies. The skills needed for interpreting various forms of medical images are thus at the core of diagnostic reasoning, and there is demand for developing systematic and effective methods for training such skills(3). An associated challenge concerns the ongoing and ever-expanding developments in imaging technology that can rapidly change the very basis of diagnostic reasoning(4). When the foundation of diagnostic methods is affected by the introduction of new technology, even experienced radiologists need to re-calibrate their analytical methods and interpretative skills(5, 6).

A common approach in advanced training for the professions is the application of some kind of apprenticeship model in which students work with and observe experienced clinicians as they act in real settings. This approach to learning possesses many advantages, but is not free from shortcomings. The general apprenticeship model builds upon an epistemic asymmetry between two nodes where the knowledge is both fixed in scope and owned by the master. Even if this configuration does enable novice learning, it provides little room for the entire organisation to develop its accumulated knowledge base in the face of changed conditions(7).

In search for more advanced pedagogical methods for the training of professionals, the research group has aimed to design effective training models that can address the learning needs of students, as well as faculty, with varying degrees of experience in radiology. This undertaking has addressed the needs for developing forms of learning that are able to keep up with the rapid pace of technological development and enable successful use of such innovations before any formal education has been put in place. The work draws upon existing research into methods for teaching professional modes of reasoning by promoting active involvement by all participants in problem-solving processes(8).

Previous studies have comprised a multitude of approaches, such as 'Clinical Reasoning Theater'(9), educational rounds(10) and computer-supported case-based learning(11). These studies clearly indicate that the demonstration of expert reasoning in examples of positive diagnosis and the opportunities for learners to discuss and reflect upon the process of reasoning are key factors for successful learning. Similarly, the use of real cases has been shown to be advantageous in representing the variation and ambiguity of clinical symptoms. There is also support for the importance of immediate feedback and exposure to diagnostic reasoning early in the learning curve(12). One further finding of particular interest concerns the use of shared visual fields that are open to manipulation. When striving to clarify professional reasoning, this type of presentation can encourage group participation and associated collective knowledge that may be modified through group interactions aimed towards a common goal(13).

For novices, as well as for experts in the field of radiology, it is often demanding to interpret radiological section images. Since these images consist of greyscale images in different planes, exclusively based on the differences in attenuation of tissues, the interpretation of what they represent is far from straightforward. Among other things, this involves how to identify objects and how these correspond to various anatomical structures. Furthermore, if a suspected object is identified in the two-dimensional image, it can be hard to judge where it is located in the three-dimensional body. Another difficulty is to assess if such objects are to be regarded as pathological or as a variation of the normal anatomy.

Based on the reviewed pedagogical principles, what became called a *Technology-enhanced Learning Session* (TLS) was developed. The design involved a set-up of imaging technologies and an interactive format that was intended to facilitate discussions between experienced radiologists and novices in the field. The primary aim of the work carried out during the TLS was to improve diagnostic accuracy following the introduction of tomosynthesis at a thoracic radiology department and to identify potential pitfalls regarding nodule detection in this new modality. The secondary aim was to investigate to what extent and in what ways the TLS could simultaneously support novice learning.

The present article is focussed on the secondary aim of the TLS and starts from observations made in a prior study that investigated the effects of the TLS on the detection of pulmonary nodules. In this initial study, a number of observers with varying experience of chest tomosynthesis analysed tomosynthesis cases for the presence of nodules. The same tomosynthesis cases were analysed before and after the TLS, and the difference in performance between the two readings was calculated. The results showed significant improvements in performance after the TLS for observers inexperienced in tomosynthesis(14). Whilst this analysis provided evidence *that* the intervention indeed had been successful, it gave few insights into *why* this was the case. The present study, therefore, re-visited the previously collected data, but instead of addressing the outcomes, as measured by observer performance, a different set of questions were posed. By grounding the new analysis in video recordings of the actual process, the study first addresses ways in which the TLS could display and instruct inexperienced observers in professional modes of reasoning. Secondly, it opens up a discussion on the ways the findings can be generalised to inform the design of basic and specialist training involving new imaging technologies.

DESIGN OF THE TECHNOLOGY-ENHANCED LEARNING SESSION

The TLS was designed by an interdisciplinary research group from the departments of radiation physics and radiology in cooperation with researchers in the learning sciences. The design of the session was prefaced on the assumption that more deliberate and systematic methods for exploring the criteria for making judgements would improve diagnostic accuracy.

To support this, there was a preparatory phase of the TLS where the observers first performed individual assessments of nodules in tomosynthesis examinations and thereafter received individual feedback on their results. As a second phase, there was a collective review session. Here, the individual results of the observers as well as the reference answers and the corresponding tomosynthesis and computed tomography (CT) images were displayed on large screens (see Figure 1). One radiologist responsible for the reference

Figure 1. The CT and tomosynthesis images are projected on a screen in front of the room.

answers navigated the CT images, and another researcher navigated the results of the tomosynthesis assessments. For each assessment, the observers were asked to give their reasons for making false positives, false negatives or giving low ratings to true nodules.

In order to assess which qualities of the TLS facilitated improved professional modes of reasoning, an analysis that could account for how the observers produced this in practice was needed. It should be made clear that the analysis did not seek to explain factors affecting learning, but rather targets those enabling conditions or qualities of the learning process that create the opportunities for improved professional judgements. By investigating the consistencies in how these judgements were disseminated to those involved, including the less experienced observers, a number of critical conditions were highlighted.

ANALYSIS OF THE TECHNOLOGY-ENHANCED LEARNING SESSION

The TLS study on how best to judge radiological section images produced by a new technology highlighted three interrelated conditions of the TLS approach to developing professional diagnostic judgements. These conditions are presented and discussed.

Juxtaposing past and present actions

In order to understand how the TLS could contribute to an understanding of the ways in which experienced radiologists make their decisions (for the benefits of novices), it is important to outline how the session, and the technologies involved, were arranged. One significant premise was that the results of each individual rating and the results of the reference method were displayed in a field next to the projected tomosynthesis image (see Figure 2). Another premise was that these appeared simultaneously as the annotated tomosynthesis section image was shown. Through this specific arrangement, each individual answer could be instantly compared with (1) the 'true' answer (is this a nodule or not), (2) the results of the other observers' answers and (3) the object in the image to which the classification referred. Technically, this was made possible using the visualisation software ViewDEX[15–17].

Epistemic asymmetry and accounting practices

There were several implications of the particular juxtaposition of outcomes. First, both the correctness and incongruences of earlier answers were effectively displayed. Every single mistake was thus established as an inescapable fact open for general review. As a result, when the past actions were shown to be incorrect, this called for some kind of 'corrective action'. Frequently when one of the more experienced radiologists was responsible for an incorrect outcome, they would initiate an exploration of the grounds for their own assessment. Typically, such accounts started with statements such as 'is this on me?' or 'I'm responsible' and would then develop into possible ways to analyse the specific case. For the benefit of the less experienced observers, these extended accounts would act as models of advanced diagnostic reasoning, typically pertaining to borderline cases or particularly difficult areas.

These accounts also reveal one of the more sensitive aspects of the TLS. As a part of the design, there was an epistemic asymmetry in the group of observers, with four experienced specialists in thoracic radiology and three non-specialists. For professionals, the opening up of their actions to scrutiny by peers, and even less experienced participants, could be uncomfortable and requires a large degree of mutual trust. Even if this practice may be contrary to expected hierarchy and normal processes, it was perceived to be an important element when striving for improving

Figure 2. The visual representations used during the TLS. CT (left), TS (middle) and compiled answers (right).

professional diagnostic capabilities in general. In this way, professional judgements were not only being challenged, but it was also being clearly demonstrated and analysed by discussion to what standard and by which methods the group would deem any judgement valid for the clinical application of a new technology.

The inclusion of inexperienced observers also resulted in additional mistakes in the batch of cases to be discussed. Rather than regarding this as a flaw in the design, it should be considered an important resource. As a consequence, a large number of cases became objects for clarification that required further explanation. Such explanations were implemented, i.e. communicatively designed, in ways that were also comprehensible for non-specialists in the field. Consequently, knowledge/awareness, that under normal conditions would be *taken for granted* in communication between specialists, now had to be *articulated*.

Moreover, as the TLS arrangement provides an opportunity for elaborating the reasons for all mistakes, the discussion was not limited to a selection of cases regarded as typical or noteworthy from some pregiven point of view. In this way, a broad range of problematic interpretations associated with the variability of human anatomy and pathologies were discussed. Throughout the session, a number of interpretative pitfalls were thus found and formulated.

Coordination work displayed

A central constituent of the TLS for making judgements public was the simultaneous use of two separate projector screens. All participating observers (equipped with laser pointers) were facing these screens, which served as a shared point of reference. The fact that two projections were arranged side by side allowed for comparisons of the CT and tomosynthesis images and enabled constant assessments of each highlighted structure and the corresponding structure as it appeared in the reference method. However, since the systems did not have comparable coordinate systems that could define the exact corresponding localisation, comparisons were not immediately available. Furthermore, due to the two different types of imaging technologies involved, the same structure would look dissimilar in the two images. Adding to this, the tomosynthesis images were only available in the frontal (coronal) plane, whereas the preferred view of the CT scans was the transversal section images (see Figure 1).

Although these differences might be interpreted as putting extra demands on the observers, it was found that the work needed to organise the two imaging systems in alignment constituted important grounds for uncovering implicit radiological reasoning. This work necessitated concerted effort by the two participants controlling the computers as well as the group of observers. New cases were first opened up in the tomosynthesis material. Although the radiologist responsible for the reference method had noted in advance where the corresponding structure should be located in the CT images, additional effort was required in order to determine the exact section image that best matched the highlighted structure. The group of observers regularly guided this coordination effort. Moreover, it was commonly requested to also see the adjacent sections in the tomosynthesis stack, which did not always coincide with the highlighted region. In this way, it became possible to discern in which section the structure was most clearly visible, and thereby, to establish a more precise perception of its localisation. Through this manual calibration, a solid relation between the two technologies was reached, making sure that the two representations corresponded to the same object.

A central component in the diagnostic work of finding suspected nodules is to grasp their precise location. Thereby, the work of aligning the two representations fulfilled several purposes. Most importantly, it clarified the means through which decisions about localisation are made. In this work, a number of resources central to the practitioners' diagnostic reasoning came into view, such as knowledge about anatomy for navigating the regions of interest, search routines for reading radiological section images by scrutinising sequences of images and methods for precisely pinpointing significant features of the lung.

DISCUSSION

The design of the TLS built on earlier work pinpointing a number of essential features of successful learning environments: the demonstration of expert reasoning, the use of authentic cases, the sharing of a reference space for learning, and opportunities for discussion and reflection(8–10). Even if these findings acted as an introduction for the current study, the new results expand on the understanding of their application. In addition, the present analysis clarifies the outcomes of the previous study by the research group(14). This demonstrated that inexperienced observers improved their detection skills after taking part in the TLS. In highlighting some interesting features of the TLS, the present analysis adds to the understanding of *how* such improvements were reached.

One major outcome of the analysis is the central role played by broad-based visibility. That is, the visibility both of diagnostic reasoning in action and the material grounds on which this reasoning was based. In the TLS, competent detection was made transparent and turned into instructions for the less experienced. The problem of coordinating the two image representations is a case in point. A technological approach to the matter would probably suggest that this task should be automated and handed over to the technology. On the contrary, the findings show that such a move would come at a pedagogical cost. The work needed to perform the calibration was exactly what brought radiological reasoning into view. Through this work, the reasoning and skills of the experienced observers, particular and domain specific as they are, became evident features in the TLS, i.e. things to be seen and learned.

One part of the educational design was the inclusion of preparatory work by each observer. This meant that much time and effort had been invested in working through the cases. It was also known that the assessments would be subjected to scrutiny under a collective regime at a later stage. Arguably these experiences would serve as grounds for taking part in the ensuing discussions. Through this relation between past and present, the TLS targeted diagnostic reporting practices. The use of openly available records of past actions triggered a number of reports—extensive explanations and close examinations of mistakes and their corrections. Given the difference between observers, the comments provided had to be constructed in ways that displayed sensitivity to the variation in participants' experience and enabled everyone to take part. This detailed level of description was additionally motivated by the presence of the new tomosynthesis technology for medical imaging. In the process of reaching consensus, tacit understandings or things that had been taken for granted were revisited and collectively reviewed. Again in relation to the less experienced observers, this discussion served as a form of elaborate and detailed instruction in active professional reasoning.

Implications for design

In the present work, the success was created by the integration of novel imaging technologies in the workplace with specific forms of interaction. Based on the analysis of outcomes, three principles are proposed—ideas to be considered when designing learning environments for teaching professional modes of reasoning in radiology:

- *Ensure accountability of past and present actions*: The ways in which participants with different levels of experience interact and communicate have a large impact on the outcome of the activity. By displaying records of past actions, everyone can become involved and mistakes become dissected rather than hidden.
- *Exhibit work in action*: Experts working on authentic cases give prominence to case-specific details, disambiguation practices, and several dimensions of variation (in representations, anatomy, pathology etc.). Professional modes of reasoning, when being made publically visible, then operate as instructions.
- *Provide participants with shared access to visual materials*: Given different set-ups, participants will have different possibilities of establishing shared references and partake in reasoning that can build on visual details. As was noted, the observers' ability to notice, discuss and investigate particular features of the radiological images became a necessary requirement for the accomplishment of their collaborative group working.

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