Lifelong learning in radiology

Valorisation

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This valorization addendum reflects on how the findings of this Ph.D. thesis on lifelong learning in Radiology can be utilized outside of the scientific field. First, the public relevance of this thesis will be discussed. Second, the main findings and potential strategies to support lifelong learning in radiology will be discussed. Third, the intended audience for the valorization of this thesis is described.

Public relevance

Many physicians are nowadays involved in the evaluation of medical images. Let us start with an everyday example of medical care in the Netherlands: A patient wakes up in the middle of the night, experiences serious dyspnea, and has developed a fever. He or she needs to go to the hospital. A clerk and a resident in internal medicine accommodate our patient. They suspect pneumonia and therefore request a chest radiograph to obtain more information about the current state of the patient's lungs and heart. Radiographs are generally considered complex to evaluate. The clerk and the resident evaluate the radiograph themselves, yet they struggle to come to conclusions. Therefore, they call the attending resident in radiology. The attending resident also evaluates the image and draws preliminary conclusions. Based on the preliminary conclusions, the resident in internal medicine starts a treatment plan. The next morning, a senior radiologist checks and finalizes the preliminary report of the resident. In this example, four (future) physicians are involved with only one radiograph. So how are all of these physicians trained to evaluate medical images?

The findings of this Ph.D. thesis indicate that all the physicians from the example have different training needs. Therefore, different strategies are necessary to support their learning experiences. The clerk, who may be considered a novice in evaluating medical images, probably received little training in evaluating chest radiographs. To support the learning experience of novices, it is necessary to focus on different aspects of current image evaluation training. The resident in our example can be considered an intermediate learner in the evaluation of medical images; he/she will have seen various normal and abnormal medical images already as they evaluate radiographs on a daily basis. Intermediates will particularly benefit from feedback on their own evaluations of medical images. For intermediates, it is therefore advised to provide in-depth feedback on their evaluations, as frequently as possible.

The radiologist of our example, who is an expert in evaluating chest radiographs, will have continued learning experiences throughout his/her career. New imaging techniques frequently become available, and experts will need to keep on adapting to an ever-changing medical field. For experts, additional support in implementing new imaging techniques into their everyday clinical practice is therefore advised.

Even though novices', intermediates', and experts' learning experiences substantially differ, all these physicians share the same, universal goal. They all strive to improve their image evaluations to provide the best possible care. By improving their learning experiences, their evaluations should subsequently improve. Improved evaluation skills should finally lead to fewer diagnostic errors and, thus, improved patient care.

Supporting learning of novices in radiology
For novices, many initiatives have already been developed for teaching medical image evaluation. Many medical students are trained with a lecture, followed by some practice cases and feedback to evaluate chest radiographs in a semester about cardiopulmonary diseases. Such lectures consist of basic cardiopulmonary anatomy, the radiological manifestations of some diseases, and instruction to always evaluate radiographs in the same, similar order, called a systematic viewing strategy. Our investigations show that there is a mismatch between the prevalence of diseases in image evaluation training and (future) medical practice: In image evaluation training, the prevalence of diseases is generally high, while most medical images in clinical practice are normal. This mismatch may impact the decision-making process of (future) physicians and may lead to more false-positive evaluations. Thus, a higher proportion of normal images in image evaluation training is advised.

Moreover, it is debated when to provide a practice phase with radiograph cases in image evaluation training. Medical students could practice before they receive an expert's explanation in a lecture, whereby they have to figure out solutions for themselves. Moreover, medical students could also practice after an expert's explanation, in order to check whether they understood this expert's explanation. Our findings show that for image evaluation training for medical students, the timing of practicing with radiograph cases does not matter for the detection of abnormal areas (lesions). Since a sequence with expert' explanation followed by practicing is generally more time-efficient, this sequence is advised for medical students' image evaluation training.

Additionally, this thesis' findings indicate that teaching a systematic viewing strategy to medical students does not lead to increased detection of lesions on chest radiographs compared to a non-systematic (random) viewing strategy. Radiology teachers are therefore advised to focus on particularly the anatomy, the normal findings on radiographs, and the radiological manifestations of diseases instead of teaching viewing strategies.

Supporting learning of intermediates in radiology

Intermediates, such as radiology residents, could particularly benefit from additional and in-depth feedback on their own evaluations. Eye-tracking techniques capture where, when, and for how long a person has looked and could provide new and rich feedback to intermediates. In one investigation of this thesis, the first-year residents' eye movements were captured 11 times during their first year of residency training, while they were evaluating chest radiographs. One innovative aspect of a study on the longitudinal development of residents of this thesis is that the findings of this study may be used as a reference category of eye movement development: The eye movements of residents, while evaluating chest radiographs, could be regularly captured with eye-tracking technology during their first year of residency training. Their eye movement patterns can subsequently be compared to the eye-movement patterns of our longitudinal investigation. Such a comparison could provide residents with an additional source of feedback to monitor their development.

Additionally, eye-movement patterns could also provide in-depth information to residents on how their image evaluation takes place. Since eye-tracking technology is capable of capturing where, when, and for how long a person has looked, it can tell what specific areas of a radiograph residents have not laid their eyes upon. Such information on the evaluation process could be combined with information about whether residents missed lesions on that particular radiograph. Information about the evaluation process, with eye-tracking technology, and the outcome of the evaluation, such as missed lesions, could provide in-depth and more complete feedback to residents. Residents could use such information to improve their image evaluations.

Supporting lifelong learning of experts in radiology

Finally, eye-tracking methodology in medical image evaluation research has been primarily used to improve our understanding of how learning to evaluate images takes place. Another innovative aspect of this thesis is that one of our studies focused on senior radiologists learning to work with new imaging techniques. Recently a new imaging technique, contrast-enhanced mammography (CEM), has been introduced, which consists of a conventional radiograph of the breasts (mammogram) and a contrast-enhanced mammogram. CEM is superior for the detection of breast cancer lesions compared to conventional mammograms only. Radiologists were previously advised to evaluate the contrast-enhanced image after the conventional mammogram. Our investigation showed that an evaluation order with the contrast-enhanced image before the conventional mammogram led to similar detection rates of breast lesions, yet the evaluation was 33% more efficient compared to an evaluation order with the conventional mammogram followed by the contrast-enhanced mammogram. With eye-tracking methodology, it was unraveled that particularly the analysis of potential lesions was more efficient, not the detection of lesions. Overall, the use of eye-tracking methodology led to new insights into how this new imaging technique could be used most effectively and efficiently in everyday medical practice. Therefore, to implement new imaging techniques into experts' everyday medical practice, studies with eye-tracking methodology are advised.

Intended audience

In the last decades, radiological images have become widely accessible throughout hospital facilities through their digitalization. Therefore, many (future) physicians, from medical students to senior radiologists, evaluate radiological images on a daily basis. This thesis investigated this whole spectrum of learners in radiology. Therefore, the intended audience for the knowledge valorization of this thesis is physicians involved in the evaluation of medical images.

However, radiological images are not the only images that contain abundant information about the function and dysfunction of the human body. In our example, only a chest radiograph was obtained. In everyday medical practice, however, other medical tests are frequently ordered for an even more complete picture of the patient. One could think of electrocardiograms and laboratory blood tests, as well as pathology slides to be examined under a microscope by a pathologist.

Such medical tests, which also contain visualizations or representations of the human body, are also considered complex to evaluate. Therefore, the findings of this thesis on lifelong learning experiences in radiology could also apply to learning to evaluate these medical tests. It should be noted that pathology slices are generally evaluated by pathologists and residents in pathology only. For the field of pathology education, our findings on learning experiences may thus primarily apply to the spectrum from intermediates to experts. By contrast, other medical tests, such as electrocardiograms and laboratory blood tests, are generally evaluated by a broader range of physicians with different expertise levels. Therefore, the findings of our investigations can have added value for the whole range from novices to experts in learning to evaluate electrocardiograms and laboratory tests.