Human-computer interaction in radiology

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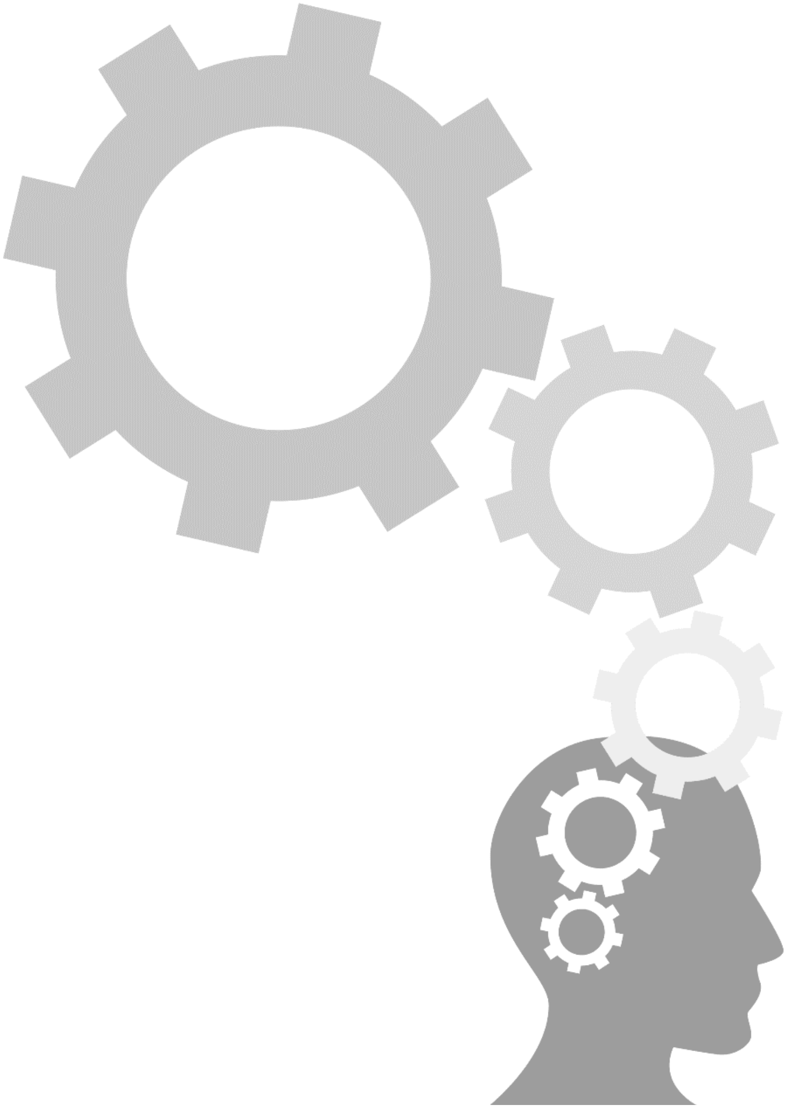
Future perspectives



Usability evaluation

As digital technology evolves, increasingly complex and diverse computer systems enter the radiology workspace. In order to ensure that users can use these systems effectively, efficiently, and enjoyably, the vendors of these systems have to incorporate usability engineering methods into their development processes.

The FDA [1] and IEC [2] have constructed guidelines for usability evaluation with which vendors have to comply. Although it is good that these regulatory organizations place demands on the usability of medical systems, it is unclear whether the methods they propose are the most effective. More research is needed to compare the effectiveness of various usability evaluation methods in order to improve the regulatory guidelines. It would help greatly if vendors would make the data of their usability evaluations available for research purposes. However, care should be taken to ensure that sensitive information about their products does not fall into the hands of their competitors.

The FDA and IEC guidelines focus heavily on preventing use errors. While this is arguably the most important goal of usability engineering in healthcare, it should not be the only goal. Efficiency, user satisfaction, and general effectiveness (not related to use errors) are also important for a product's overall usability, and should therefore be taken into account during the usability engineering process. However, there is currently no clear incentive for vendors to include these usability aspects into their usability evaluations (the incentive for usability evaluations focused on use error prevention is clear: if this is not done properly, the product will not receive FDA/IEC approval). If hospitals also start placing demands on usability, as was argued in Chapter 2, vendors might be more inclined to cover the full scope of usability evaluation in order to increase the probability that a hospital will buy their product. Future research could also contribute by studying the effects of different scopes of usability evaluation on product success.

A challenge for radiology that is already relevant today, but will become even more relevant in the future, is to ensure that all the different and interdependent systems that make up the radiological IT infrastructure are properly integrated. There is a need for more research on the interoperability of different systems and how this affects their usability. Our results in Chapter 3 indicate that a substantial number of usability issues encountered in one system were actually caused by issues in another system, or by issues in communication between the systems. We need to determine how these kinds of issues can be predicted and prevented before deployment of a system.

Inconsistencies in the user interfaces of different systems can also lead to usability issues. More work is needed to harmonize the interfaces of different systems (e.g. CT and MR scanners) so that users working with multiple systems have a consistent user experience.

We believe that many opportunities for learning about usability in radiology lie in post-deployment usability evaluations. In contrast to pre-deployment evaluations, which study simulated use, these evaluations allow us to evaluate the usability of a system in a real-world setting. This can provide valuable insights into the use of a system in clinical practice, the effects of use environment and user demographics on usability, interoperability issues, and how system usage changes over time.

Although post-deployment usability evaluation is an integral part of the usability engineering life cycle [3], there is little quantitative evidence that supports its effectiveness. In order to convince vendors to invest in post-deployment usability evaluation, we need to systematically evaluate the added value of post-deployment usability evaluation with respect to pre-deployment evaluation.

New imaging technologies (e.g. spectral CT) will change the way radiologists view and interact with image data of the human body. This opens up a lot of new possibilities, but it also creates usability challenges. New interfaces need to be developed that effectively display new types of image data, and clearly distinguish between different types of data (e.g. so that radiologists do not confuse spectral CT images with conventional CT images).

Interaction techniques

Changes in technology bring changes in user interaction paradigms. An example of a recent technology that has transformed user interaction in radiology (and in the rest of the world) is the touch screen. Most of the hardware controls on imaging modalities have been replaced by touch screens, and smartphone and tablet versions of imaging software are increasingly common.

Many more of such technologies (e.g. gesture-based devices, brain-computer interfaces) will enter radiological practice in the future. It is important that adequate interaction techniques for these systems are developed that allow radiologists to interact with them effectively and efficiently.

Future research should evaluate the performance of multiple interaction techniques for basic radiological interaction tasks (e.g. navigating through a stack of images, performing measurements). Product vendors can then use the results to inform the design of their products.

User interface customization

User interface customization provides a way to manage the increasing complexity of radiological software. Complex software should be customized to the needs and preferences of each individual user and each different context of use. However, the best way to achieve effective interface customization is still a topic for future research.

In Chapter 6, we showed that intelligent support for interface customization increased radiologists' customization effectiveness compared to when they customized on their own. Future research should determine the optimal interface for delivering such customization support, and expand the scope of the support. The support could include, for example, display protocol customization, report customization, and context-based customization.

Computer-aided diagnosis

Advances in image processing and artificial intelligence will enable the development of more powerful CAD systems. We believe that future radiologists will reach their diagnosis in collaboration with one or more of these systems. In order to maximize the performance of the radiologist-CAD team, we need to optimize the radiologist-CAD interaction.

In Chapter 7, we studied an important aspect of this interaction: trust. We identified several ways to change CAD's output so that it facilitates more effective trust calibration. Future research should empirically study the effectiveness of our suggestions.

Although there is abundant research on CAD, most of it focuses on improving CAD's performance or evaluating its effect on radiologists' sensitivity and specificity. While this is obviously important, we also need a deeper understanding of the psychological aspects of the radiologist-CAD interaction, so that we can design the user interfaces of CAD systems in such a way that they become the perfect artificial partners for the radiologist.

Structured reporting

A current trend in healthcare is to leverage big data in order to improve patient care. Since the radiology department generates large amounts of data, it could play an important role in this process. However, a limiting factor is the way that the results of radiological exams are currently being stored. The department's final product, the radiology report, is often constructed in a unconstrained and unstandardized way, which makes it difficult, or even impossible, to use the information in the report for data mining purposes.

Therefore there is a need to structure and standardize the information contained in the radiology report. A solution that is currently being explored, and in some cases already used in clinical practice, is to have radiologists use structured reporting software that lets them report in a highly controlled fashion. In Chapter 8 we developed an alternative solution that uses natural language processing techniques to automatically convert free-text radiology reports into a structured format. This has the advantage that it does not require additional actions on the radiologist's part and does not interfere with image viewing and interpretation.

More research is needed to further develop these kinds of systems, and to test them against structured reporting software. In this way, we can determine the best way to obtain structured radiology reports.

Future radiology workspace

When taken together, the elements of human-computer interaction studied in this thesis allow us to paint a picture of the radiology workspace of the future. In this workspace, all hardware and software with which radiologists interact will have undergone rigorous usability testing, creating a great user experience for the radiologists and ensuring that they can perform their jobs effectively, efficiently, enjoyably and safely.

The different technologies radiologists use will be seamlessly integrated, creating a technological environment that the radiologist perceives as one integrated whole. This is facilitated by improvements in IT standards such as DICOM and HL7, and increased collaboration between vendors through connectathons (e.g. the IHE [4] and FHIR [5] connectathons) and other interoperability efforts.

Radiology user interfaces will become increasingly intelligent. They will assist radiologists in customizing the interface to their individual needs and preferences and automatically adapt to the situation at hand. Radiologists only see the functionality they need for the current step in their workflow for the study they are currently reviewing. Intelligent interface agents will also be able to take mundane tasks out of the radiologist's hands. For example, they can optimize radiologists' worklists, automatically create structured reports, and calculate imaging biomarkers for a patient.

These improvements in usability, interoperability and user interface intelligence will reduce the cognitive overhead radiologists face while interacting with technology and thereby allow them to spend more cognitive resources on actual patient diagnosis.

Artificial intelligence will also become more prevalent in diagnosis itself. The radiologist will form a diagnostic team with advanced CAD systems and clinical decision support systems. The performance of this team, both in terms of diagnostic accuracy and reading efficiency, will be higher than the performance of any radiologist alone.

Advancements in mobile technology will loosen the ties between radiologists and their desks. They can view images anytime and anywhere, thereby increasing their flexibility, their visibility within the hospital, and facilitating face-to-face communication with their colleague radiologists, radiology technicians, and other medical professionals.

Novel hardware will open up new ways to visualize and interact with medical image data. For example, interventional radiologists can remain sterile by using gestures to control images, virtual colonoscopy can be performed in full 3D using virtual reality glasses, and 3D printing or holograms can be used for surgical planning.

These are exciting prospects for the radiology workspace. How will they play out in reality? And which other technological advancements will transform the workspace? Only time will tell.

References

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