

User Questionnaire to Evaluate the Radiological Workspace

Peter M. A. van Ooijen, Allya P. Koesoema, and Matthijs Oudkerk

Over the past few years, an increase in digitalization of radiology departments can be seen, which has a large impact on the work of the radiologists. This impact is not only demonstrated by the increased use of digital images but also by changing demands on the whole reading environment. In this study, we evaluated the satisfaction of our radiologists with our digital Picture Archival and Communication System environment and their workspace. This evaluation was performed by distribution of a questionnaire consisting of a score sheet and some open questions to all radiologists and residents. Out of 25 questionnaires, 12 were adequately answered and returned. Results clearly showed that most problems were present in the area of reading room design and layout and comfort and ergonomics. Based on the results from this study, adaptations were made and the results were also used in the planning of the redesign of the entire department of radiology.

KEY WORDS: PACS, workplace design, ergonomics

INTRODUCTION

The growing use of digital technology in medical applications has encouraged the medical imaging field to undergo the shift from conventional film-based radiology to an increasingly digital environment. This transformation is primarily caused by the adoption of Picture Archival and Communication System (PACS) and the increase in digital imaging modalities. The radiology workspace has shifted from film light boxes to electronic work stations. To fully reach the potential improvement gained by using these technological advances, planning, design, and operation steps should be made with numerous considerations balancing between the best possible performance and the economical considerations.

Previous studies have been performed and published on two areas, the work station and the environment; most studies focus on one of these two areas.

A lot of research has been carried out on work station design and analysis of work patterns of radiologists.¹⁻⁵ When considering the work station itself, workflow is a returning theme. It is mentioned multiple times in literature that workflow should not be copied from hard copy to soft copy reading but that redesign of the workflow is required. With a good work station design, the workflow of the radiologist can achieve over 40% of increased efficiency.³ According to Moise and Atkins,³ a main focus should be put on the careful design of hanging protocols.

The radiology working environment has also been the topic of multiple studies.⁶⁻⁸ Important considerations here are the use of the room, its size, the location, and the supporting services (e.g., heating, ventilation, air conditioning, etc.). In our case, the fact that we are a teaching hospital should also be taken into account when determining the working environment.⁷

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At our department, full digital review has been performed since 2002. After 3 years of operation, an evaluation of the work station was initiated in the last quarter of 2004. The work stations are partly located in a large reading room especially designed for this purpose. The other work stations are scattered around the department and mostly located in close proximity to the acquisition devices. These work stations are also referred to as modality work stations throughout the article. These work stations are placed in readily available, nonoptimized workspaces.

MATERIALS AND METHODS

Our PACS design is based on fast availability of all images within the archive and a high level of redundancy.^{9,10} All work stations are connected to a dedicated radiology network with copper wiring (Cat5E cabling) running at 1 Gb/s. The radiology network is a subnet of the hospital network that continues to operate even when the hospital network goes down. The uplink between the radiology network and the hospital network uses 1 Gb/s fiber optic cabling. The images are provided to the radiological viewing stations through four identical (MASS) servers using load balancing. The use of four servers increases retrieval speed and also ensures operation in case of failure of a component. Furthermore, this concept allows for an easy increase of capacity by simply placing another MASS server into the network.

Functional requirements are defined for a radiological work station in a digital radiology department. These requirements are as follows: fast and easy availability of image data and of additional resources (laboratory reports, electrocardiograms, etc.), simple postprocessing and three-dimensional visualization of image data, and dictating possibilities using digital speech recording and speech recognition. To obtain an optimal situation, all these functionalities should be integrated and should all be available on one single work station with two or three displays connected. The required functionality was obtained from a selection of software packages from different vendors. Our PACS provider (Oldelft Benelux, Veenendaal, the Netherlands) was trusted with the integration of all software packages into one single work station.

The workflow of the current system is shown in Figure 1.

To evaluate the current system and to develop new improvements and designs, a structured questionnaire (Fig. 2) was presented to all radiologists and radiology residents. The questionnaire is composed of three different groups of questions in a score sheet (work station functionality, reading room, and comfort ergonomics), two multiple-choice questions, and two open questions to obtain general information (Fig. 2). The score sheet questions were rated on a five-point scale with a score of 1 for very dissatisfied, 2 for dissatisfied, 3 for neutral, 4 for satisfied, and 5 for very satisfied.

The questionnaire was sent to all 25 radiologists and residents to inquire how they experienced the different aspects of digital radiology.

The results of the questionnaires were collected and evaluated using Microsoft Excel. From the results, the mean and standard deviation as well as the median were calculated and visualized into bar graphs.

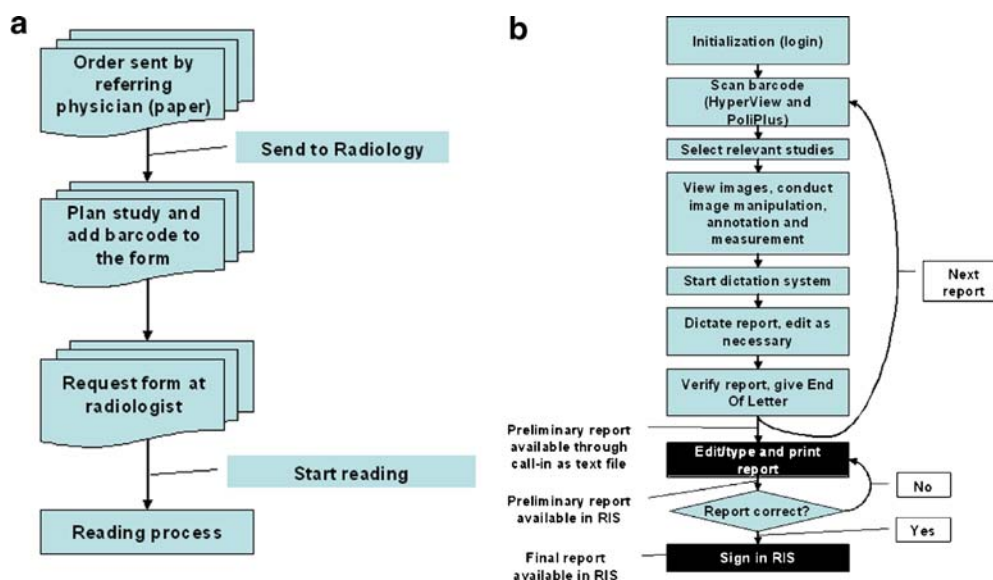


Fig 1. In the order process (left), a paper order form is still applied. The reading process (right) uses this order form as basis for the workflow. In the reading process, the two black boxes indicate process steps performed by the typing room. All other processes are performed by the radiologist. All order process steps that are taken before the reading process are performed by the administration.

Name (optional) : _____ Position : _____
 Workstation location/type most often used : _____
 Question 1-25: please indicate your satisfaction regarding the following factors in the current PACS/workstation system (1: very dissatisfied – 5: very satisfied)

No.	Parameter	1	2	3	4	5
	Workstation Functionality					
1	Overall performance					
2	Speed					
3	Image quality					
4	User Interface ease of use					
5	Login procedure					
6	Worklist performance					
7	Navigation, Patient & study search					
8	Retrieval of past studies					
9	Image viewing facilities					
10	Availability of image processing & measurement functions					
11	Image annotation					
12	Report generation					
13	Dictation system performance					
14	Computer Aided Diagnosis (if available)					
	Reading room					
15	Location					
16	Room space					
17	Layout					
18	Lighting					
19	Noise level					
20	Temperature					
	Comfort /ergonomics					
21	General comfort					
22	Chair & table position/adjustability					
23	Table layout & space					
24	Keyboard, mouse & other device placement					
	Other Functions					
25	Clinical consultation facility					
26	Clinical conference Facility					

27. Clinical consultation:

Frequency:

Method:

- ☐ Telephone
- ☐ Direct
- ☐ e-mail

28. Telephone preferences:

- ☐ Handheld receiver
- ☐ Cordless
- ☐ Headset
- ☐ Speaker phone

29. Please list below three main advantages (benefits) and disadvantages of the PACS and workstation system currently used

30. Please provide suggestions of improvement to the existing PACS/workstation system

Fig 2. Questionnaire.

RESULTS

Of the 25 questionnaires, 12 (48%) were completed and returned.

Work Station Functionality Performance

Figure 3 shows that, based on the median score, all parameters are rated at least on the neutral scale.³ The best performing parameters, with a

median score of 4, include overall performance, speed, image quality, user interface ease of use, retrieval of past studies, and image viewing facilities. Features rated low (mean value <3) are worklist performance, navigation/patient and study search, report generation, and dictation system performance. These results indicate that improvements are mainly required in the worklist/query functionality and the dictation/report generation function.

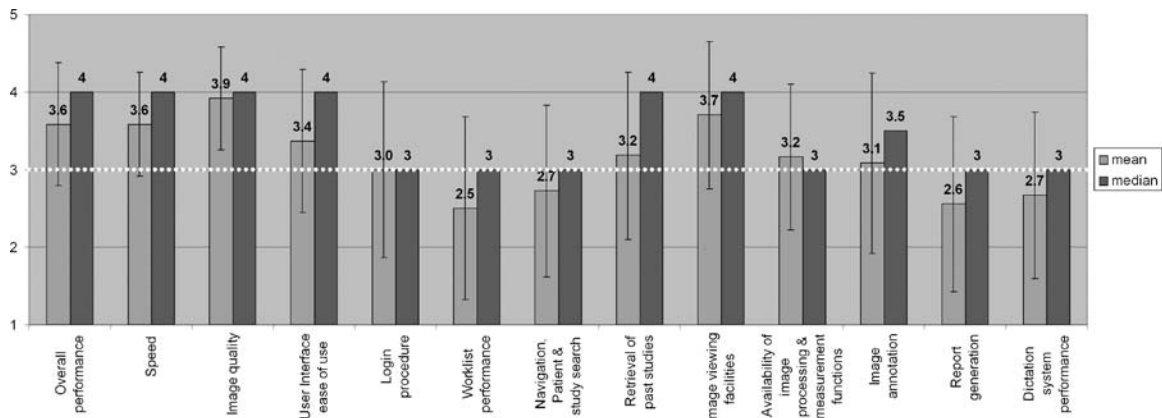


Fig 3. Results of the questions concerning work station functionality performance.

Most of the radiologists (67%; see Fig. 6) are either satisfied or very satisfied with the speed of the radiology system.

The digital image quality was rated as satisfying or very satisfying by 92% of the radiologists, with one radiologist scoring it as very satisfying (Fig. 6). One “dissatisfied” rating was given by a radiologist, indicating that the digitized x-ray quality was lower than the physical film.

Whereas the questionnaire result indicates that the image-viewing facilities are performing well (90% satisfied or very satisfied), it also shows that the tools for image measurement and annotation are rated close to neutral, which, combined with observation of the existing software, indi-

cates a good potential for optimization and improvement.

The performance of the report generation procedure, in this case the dictation system, needs to be improved (42% dissatisfied or very dissatisfied). Stated problems include too many manual interactions for the dictation mechanism, slow report turnaround, the need to hold the dictation microphone, and nonoptimal control during dictation process.

None of the respondents filled out the question about computer-aided diagnosis (CAD).

In contrast to the work station functionality parameters, it is obvious that the reading room design aspect of the system needs to be improved (Fig. 4). The median scores of location, noise level,

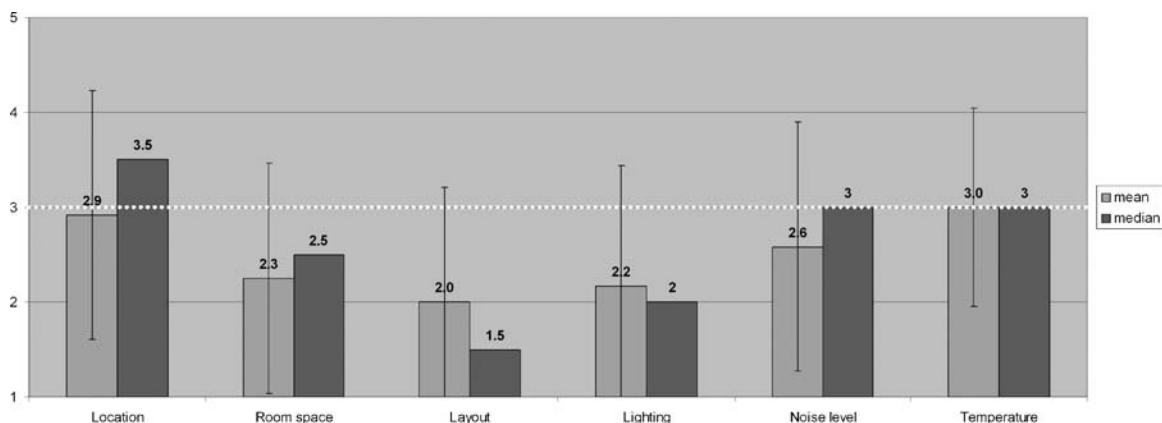


Fig 4. Results of the reading room design aspects.

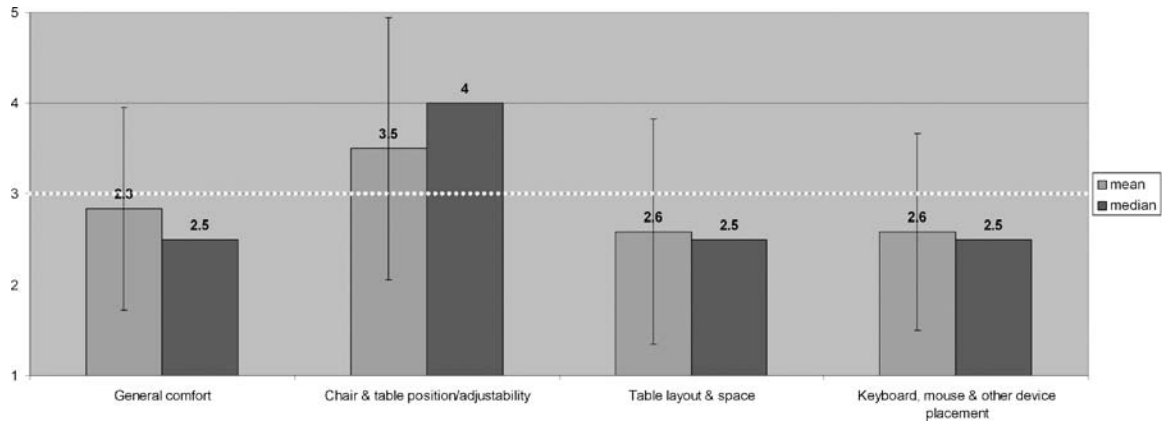


Fig 5. Results of the comfort/ergonomics questions.

and temperature parameters are rated as neutral or above, whereas the other parameters (room space, layout) are rated below the neutral level.

The general comfort has an average score of 2.8 (Fig. 5), and table layout and space arrangement, as well as peripheral devices configurations has an average score of 2.6.

Figure 6 shows that for all topics, the percentage of neutral or (very) satisfied responses is higher than 60%. In 7 out of 13 topics, over 50% of the respondents are satisfied or very satisfied.

DISCUSSION

This questionnaire aimed to obtain the opinion of our radiologists and residents about our digital radiology department.

The survey results show that the majority of the users are satisfied with the overall performance of the system. It has the fundamental functionalities and is running smoothly. The users have worked with this system for over 1 year; hence, the familiarity with the system is high.

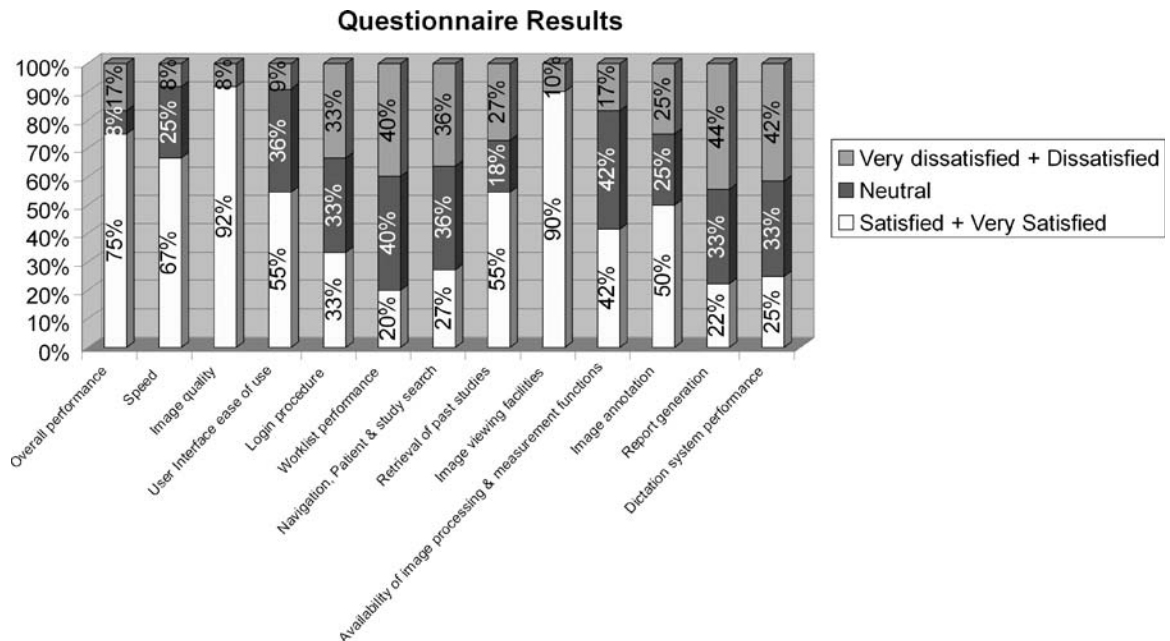


Fig 6. Satisfaction rating for each topic (percentage of respondents). Very dissatisfied and dissatisfied are grouped as well as satisfied and very satisfied.

It generally takes <1 s to load the first couple of images, which is superior to the 2-s threshold generally promoted in literature.

The user interface ease of use is an important parameter of the performance of a work station. The survey shows that although 55% of the respondents believe the user interface ease of use to be sufficiently satisfying, the others are neutral (36%) or in one case (9%) even very dissatisfied (Fig. 6). Some inefficiency in the old user interface, including workflow inefficiency, too many handlings for certain processes, and screen layout problems, should be improved.

Although the log-in procedure should be a fairly simple process, the survey shows that the respondents' opinions vary in this subject (Fig. 6). This indicates that the log-in procedure can be much improved. At the time of the survey, the log-in procedure consisted of logging in to the machine at start-up and logging in to the electronic patient file. A feasible improvement could be to design a single log-in mechanism allowing users to log-in into every program with only one user action at start-up. Another improvement could be to provide log-in information on-screen to ensure that users are working under their own log-in name.

The worklist provided is still paper based, i.e., using paper order forms issued by the requesting clinician. This form is distributed by a specific division to the three radiological teams. Although this mechanism works quite well, an upgrade into a digital/online worklist has the potential to improve the workflow efficiency.

The mechanism to navigate, query, and retrieve studies, including past studies, can be optimized, and are indicated by the questionnaire findings that states a neutral-insufficient performance level (Fig. 6).

Computer-aided diagnosis is only available on special-purpose work stations and not integrated within the PACS; the usage is therefore limited to a select group of radiologists, none of whom responded to the questionnaire. This explains the lack of response on the question concerning CAD.

The outcome to our questionnaire on the reading room design and ergonomics is similar to the results previously published by Rumreich and Johnson¹¹ Overall, the situation in our institution is slightly better, but both studies show that much

more effort has to be put into the reading room design and ergonomics.

It is indicated that the location of the reporting room is not optimal. However, the room location is a predetermined parameter and cannot be changed. If the location could still be chosen, it should be near the modalities, exit and offices, as indicated by the respondents on question 30 and also indicated by Horii et al.⁷ If possible, an outside view should be provided. The room layout and space should be arranged to give privacy for each work station, but still provide room for track and small conferences/consultations.

Lighting is one of the primary issues in the reading room design.⁷ Although high ambient lighting is favorable in general working situations, in case of evaluation of radiological images, it can cause light reflections (glare), reducing the quality of the perceived image. Currently, the reading room is mostly operated under low ambient lighting condition to reduce light reflections. Some possible solutions for the other locations where the lighting is less optimal include adjustable/dimmable lighting and task lighting or isolation of the ambient lighting from the viewing screen.

The noise present in the reading room consists of noise made by the work station machines themselves, noise from workers from adjoining work stations, and external noise, which include other workers and other devices, especially in the nonreading room modality work stations.

The temperature is regulated by the central air conditioning system, and it is currently unfeasible to have individual temperature controls for each work station in our institution because of budget limitations.

The scoring on comfort/ergonomics of the system show that this also needs improvement (Fig. 5). It was already known that the tables and chairs in the reading room are already sufficiently adjustable, whereas not all are adjustable in the other work stations (modality work stations). This fact accounts for the variety of answers in the survey result. Also, the table layout, including the placement and configuration of peripherals (such as keyboard and mouse), needs to be adjusted. Problems in table layout include lack of desk space, clutter on desk space, and nonoptimal placement of devices.

Based on the results of our questionnaire, some improvements have already been realized. First, the computer screens in the central reading room are mounted onto a ceiling mounted arm. This frees up desk space and simplifies changing the orientation of the computer screens. On these arms, task lights are fixed behind the screens. To prevent constriction of the pupils, the lights are of low brightness and can be adjusted and switched on when needed. The main reasons to keep these task lights are writing and reading of paper referral forms that are still used within our hospital.

The report status is now transferred from the radiology information system into the PACS to improve the worklist and to have a better communication as well as more ease in dictation. This way, the radiologist can see whether a report has been dictated, typed out, or approved. Additionally, the software will guide the radiologists by refusing direct dictations of data sets that already have a "set report" status. The radiologist really has to confirm if he wants to either overwrite the previous report or dictate an addendum.

An on-line recognition tool has been implemented to further improve the interaction with the speech recognition and to decrease report turn-around time. Now, the radiologist directly sees the recognized text, edits it, and approves it without the interference of a secretary.

Currently, several projects are running to further improve the set-up: First, a smartcard log-in is being investigated to minimize typing passwords and to simplify the log-in and log-out procedure. Second, the single log-in into the electronic patient record has been put on the wish list of the software developers at our information and communication technology department. Third, a new PACS viewer is developed and partly implemented by our PACS provider containing solutions to some of the indicated problems. Fourth, several radiologists now use a headset instead of a speech mike, with positive results. This headset will be used to perform dictation and will free the hands of the radiologists to operate their mouse.

Furthermore, in the rebuilding of our radiology department, the remarks made through this questionnaire are taken into account. Design con-

siderations both on the environment and on the workspace itself are based on the findings.

CONCLUSION

It is a very challenging job to provide an optimal working area for the radiologist, in a "filmless" radiology department, especially because the number of aspects to be taken in consideration is high and because the workflow is completely different from a film-operated department.

However, by continuous discussion with the radiologists, the areas for improvement have been mapped. The development of the environment, the software tools used, and the hardware have to be carefully designed and selected to achieve these improvements. If possible, these factors should be adapted to the personal preference of the radiologist.

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