Interaction techniques for radiology workstations: impact on users' productivity

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Abstract

As radiologists progress from reading images presented on film to modern computer systems with images presented on high-resolution displays, many new problems arise. Although the digital medium has many advantages, the radiologist's job becomes cluttered with many new tasks related to image manipulation.

This paper presents our solution for supporting radiologists' interpretation of digital images by automating image presentation during sequential interpretation steps. Our method supports scenario based interpretation, which group data temporally, according to the mental paradigm of the physician. We extended current hanging protocols with support for "stages". A stage reflects the presentation of digital information required to complete a single step within a complex task.

We demonstrated the benefits of staging in a user study with 20 lay subjects involved in a visual conjunctive search for targets, similar to a radiology task of identifying anatomical abnormalities. We designed a task and a set of stimuli which allowed us to simulate the interpretation workflow from a typical radiology scenario - reading a chest computed radiography exam when a prior study is also available. The simulation was possible by abstracting the radiologist's task and the basic workstation navigation functionality.

We introduced "Stages", an interaction technique attuned to the radiologist's interpretation task. Compared to the traditional user interface, Stages generated a 14% reduction in the average interpretation.

Keywords: Image display, multimodality workstations, user interface, hanging protocols, radiologist productivity.

1. Description of purpose

The radiologist has highly repetitive interpretation task, with stringent requirements of accuracy, confidence, and speed. Accessing the controls of current radiology workstations produces considerable disruption of the visual search, which may lead to differences in the volume and type of information processed [1]. We invented an interaction technique (IT) attuned to radiologist's interpretation task [2]. This technique relies on our novel approach of using stages to extend current hanging protocols for scenario-based interpretation [3]. Our hypothesis is that using workflow oriented stages streamlines the radiological interpretation task, which leads to shorter completion times and less user-workstation interaction.

2. Method

Our study investigated the impact of ergonomic controls on the observer performance in a radiology look-alike diagnostic task. A 'typical' validation of our hypothesis would have required prohibitively expensive resources, including a fully-functional radiology workstation as the test bed, radiologists as subjects, and real-life radiological images as stimuli. With the goal of performing inexpensive usability studies related to radiology workstation design, we designed a new set of stimuli and adapted the experimental task in order to test our hypothesis using a basic workstation and novice users as subjects. We aim to transfer the results from our experiment to the radiological interpretation task. This would be possible because we abstracted the radiologist's task and the basic workstation navigation functionality.

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In the radiology look-alike task, the novice subjects have to find a target in a pair of images. Typical targets are shown in Figure 1, where targets consist of images with equal sized discs splinted in half in the same direction, either vertically or horizontally.

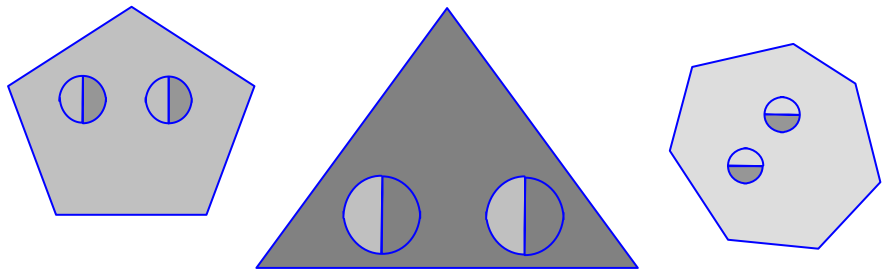

Figure 1: Typical targets

In addition to the targets, distractors such as hearts or unequal sized discs, may be present, illustrated in Figure 2. To ensure that two images must be viewed for target recognition, potential targets are represented by empty circles, as in the heptagon and the large dark circle in Figure 2.

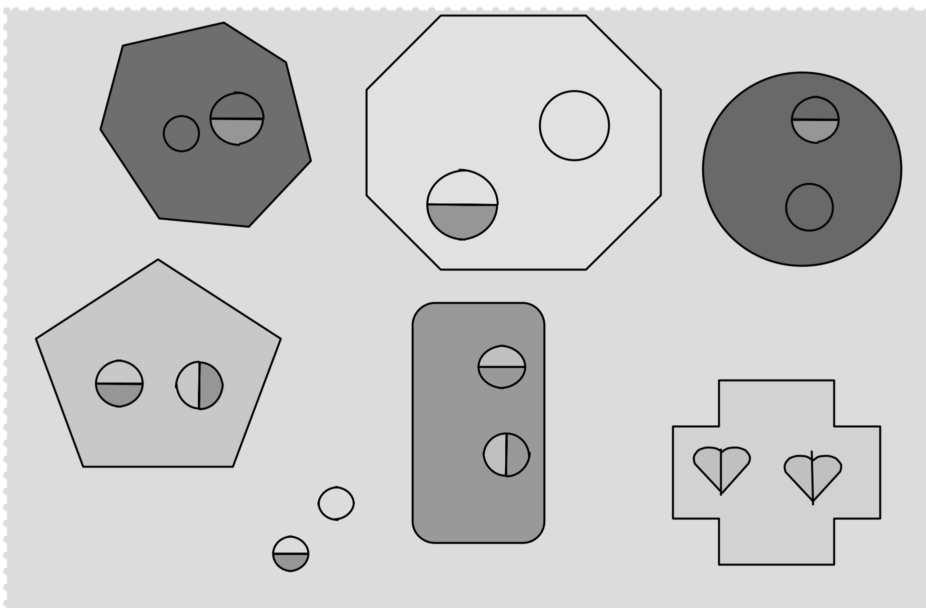

Figure 2: Distractors, and potential targets in the heptagon and the large dark circle.

To recognize a target, an image pair must be viewed, where empty circles can match anything. Figure 3 shows an image pair with the target in the octagon.

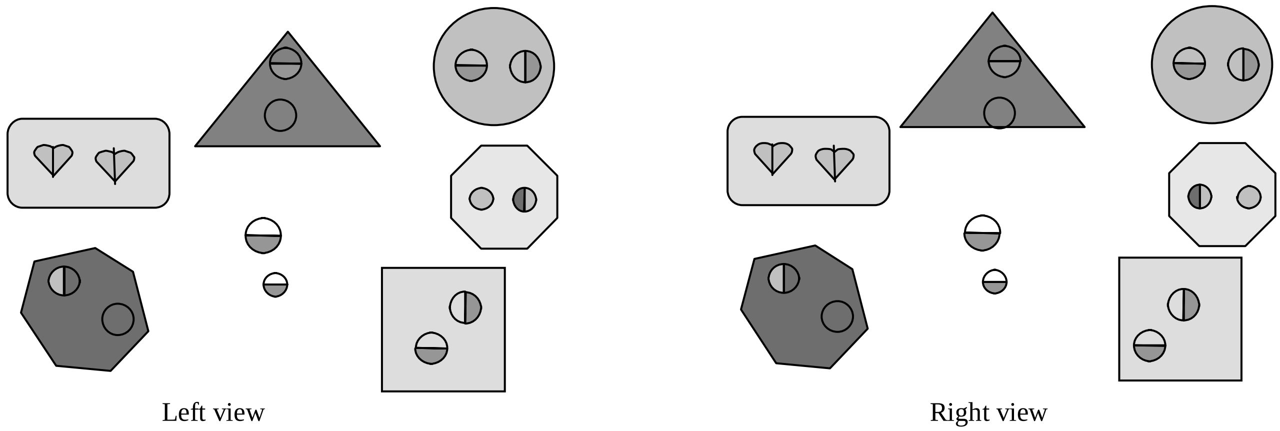

Figure 3: Image pair: empty circles can match anything. Target with two matching discs is in the octagon.

For each trial in the radiology look-alike task, a target as described above consisting of images with equal sized discs splinted in half, had to be located within the stimuli image pairs. These image pairs were arranged to resemble the posterior-anterior (PA) and lateral (LAT) views typically seen in chest radiographs, as seen in Figure 4 and Figure 5.

We compared a traditional IT called Free User Interface (FUI) with our problem oriented scenario-based interpretation IT called Stages. Stages is a user centered approach to softcopy interpretation which groups data in stages according to the mental paradigm of the radiologist. The screen layout for Stages and FUI is shown in Figure 4 and Figure 5, respectively. The only difference between the two interfaces is in the functionality of the workstation controls at the top-left.

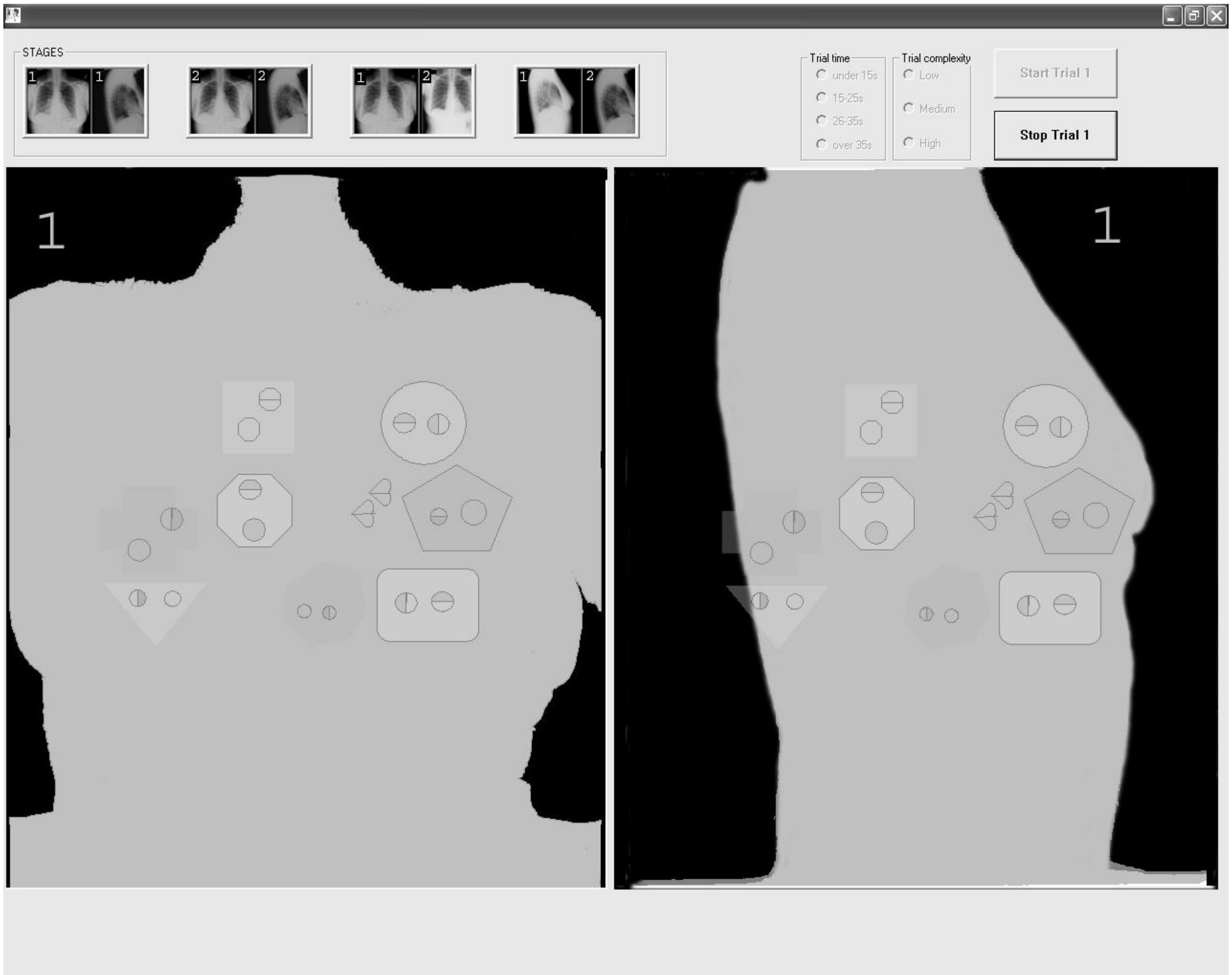

Figure 4: Screen layout from *Stages*. Study 1 is displayed. The target is in the heptagon.

Figure 5: Screen layout from *FUI*. The target is in the cross. Study 2 is displayed. The target is in the pentagon.

3. Results and discussion

The following abbreviations are used in this section:

- IT: Interaction Technique (Stages or FUI)
- SET: which of the two sets (each set had 15 trials) was used first by the subject
- METHOD: which one of the IT was used first by the subject

3.1. Response time (RT)

The RT data is summarized in Figure 6.

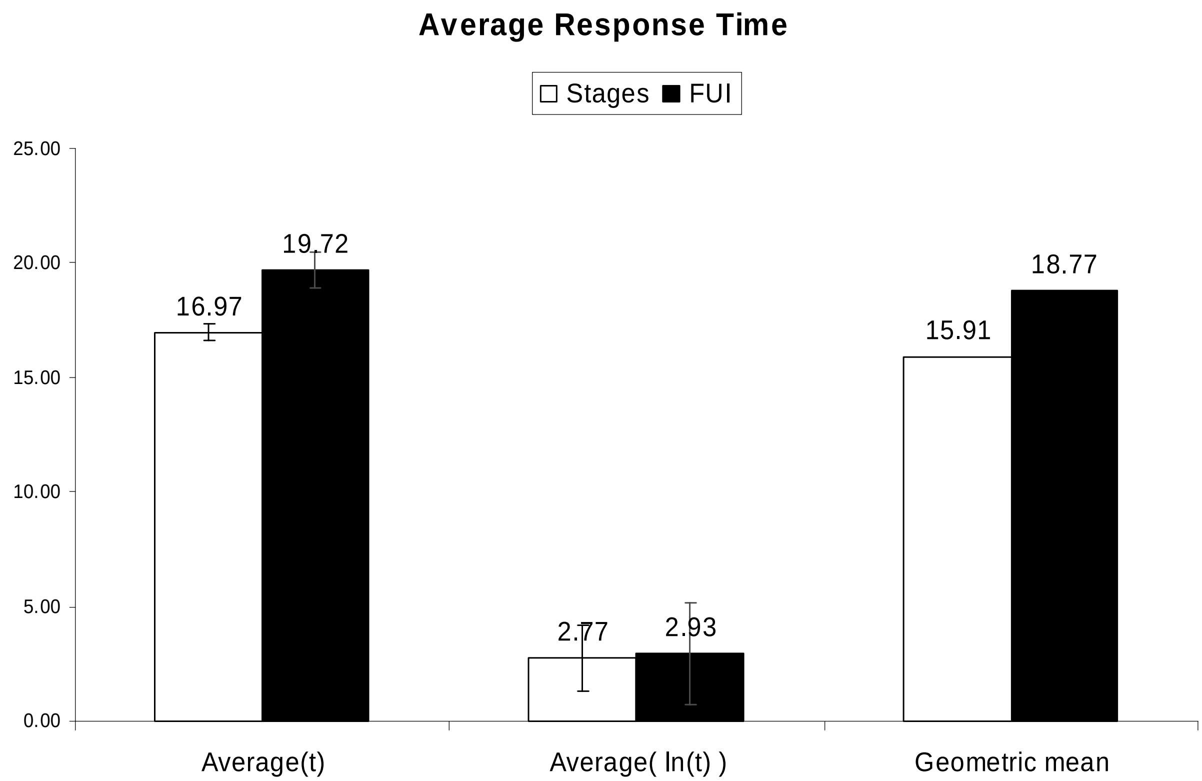

Figure 6: Average response time, calculated on both time and ln(t) coordinates. Error bars represent one standard deviation.

In order to to approximate the normal distribution, we used the Normal Q-Q Plot to compare the quantilesgquantile of the RT distribution against the quantiles of normal distribution. The RT distribution did not closely match the normal distribution (the points did not cluster around a straight line). We applied the natural logarithm to the RT data, and the Normal Q-Q Plot showed a normally distributed data. We then performed a General Linear Model (ANOVA) on the logarithm of RT, which showed the interaction technique had a significant effect on RT ($p<0.001$). The average response time was 17.0 s and 19.7 s for Stages and FUI, respectively. Since we used the natural logarithm of the RT for our statistical analysis, we will also mention the RT corresponding to the average ln(RT) values under both IT conditions: 2.77 for Stages, and 2.93 for FUI, which corresponds to 15.8 s for Stages, and 18.4 s for FUI. The average saving in RT due to the use of stages was 14%, independent of the reference used, RT or ln(RT).

The order of the in which the subjects performed using the two ITs had significant effect ($p<0.001$) on RT. For the 10 subjects that started with FUI, there was a significant improvement in performance when they performed under stages, as illustrated by the reduction in the average RT. However, for the 10 subjects that started with Stages, their performance did not improve in the second part of the experiment, when they performed with FUI. So only with Stages were our subjects able to reduce their RT as they became more familiar with the task. Consequently, we believe Stages is a better IT, as it allows the users to optimize their workflow and in to increase their productivity as they become accustomed with the main task, the visual search for targets.

4. Conclusions

This paper presents our solution for supporting the radiologists' interpretation task by automating image presentation during sequential interpretation steps. For scenario based interpretation, we extended current hanging protocols by adding stages, which group data temporally, according to the mental paradigm of the physician. We demonstrated the benefits of staging in a user study with 20 lay subjects involved in a radiology look-alike task. We designed a task and a set of stimuli which allowed us to simulate the interpretation workflow from a typical projection radiography chest reading scenario. The simulation was possible by abstracting the radiologist's task and the basic workstation navigation functionality. We introduced Stages, an IT attuned to the radiologist's interpretation task. Compared to the traditional IT, Stages generated a 14% reduction in the average interpretation time.

These results lead us to believe that vendors should work closely with the radiologists to build staged hanging protocols for various radiological scenarios, such as 'abdominal CT', 'MRI of the spine', and 'X-ray of the chest'.

5. Future work

We are validating these experimental results with local physicians. Initial comments from medical professionals suggest that our results from non-expert users can be transferred successfully to radiological softcopy interpretation tasks.

6. References

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