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Abstract: This study examines whether technology-based gaze replays of experts are effective in modeling attentional resources of novices while diagnosing medical visualizations. Contrary to findings in the literature, results reveal that eye movement modeling examples can be used as technology-enhanced instruction for novices. Diagnostic accuracy, sensitivity, and specificity significantly increased after watching the gaze replay. Learners also had significantly more fixations on task-relevant and significantly fewer fixations on task-redundant information. Implications for medical education are discussed.

□ntroduction

Experts outperform novices in the interpretation of medical visualizations (Gegenfurtner et al., 2009; Helle et al., 2011). One reason for experts' superiority is their efficient allocation of attentional resources toward diagnosis-relevant information. □y contrast, novices fixate on task-redundant information and may thus miss diagnostically important areas of the visualization (for a recent meta-analysis on expertise differences in the comprehension of visualizations, see Gegenfurtner et al., 2011). As a remedy, experts can model their efficient visual search and detection procedure to novices, for example through eye movement modeling examples (e.g., Litchfield & □all, 2011; Van Gog et al., 2009). Here, the gaze of experts is first recorded with an eye-tracking device and then superimposed on the screen. This gaze replay can function as a perceptual procedure cue for novices to direct attentional resources from task-redundant to task-relevant information, which ultimately can help students become more accurate in visualization interpretation. Surprisingly, however, the study by Van Gog and colleagues demonstrated that the technology-based gaze replay of experts had *detrimental* effects on novices. This finding may have resulted from the rather simple type of visualization used: expert gaze replay may thus have provided redundant information. Van Gog et al. (2009) call for testing the effectiveness of eye movement modeling examples with more complex kinds of visualizations, as they are typically found in medicine(Sepp□nen, 2008). In a response to this call, the present study aims to answer the question whether technology-based gaze replay of experts can model diagnostic performance of novices in medical education.

□ethod

In this section, we present the methods used to answer our research question. Particularly, we report information on participants and material; procedure; and the measures taken.

Participants and Material

Medical students' diagnostic performance in interpreting PET/CT visualizations was compared before and after exposure to eye movement modeling examples. Participants were 18 undergraduate students of medicine (10 women, 8 men, M_{age} = 21.78 years, SD = 2.15) with no self-reported prior knowledge in interpreting PET/CT.

The eye movement modeling example consisted of a 158-sec. digital video. Figure 1 shows a screenshot. The expert was asked to behave didactically during PET/CT diagnosis—that is, the expert was to model the typical way to go about solving tasks of this kind.

Procedure

Participants diagnosed two patient cases: one before and one after the modeling example. There was no time restriction. Participants diagnosed the patient cases in individual lab sessions. Patient cases were displayed in a DICOM (Digital Imaging and Communications in Medicine) standard used in hospitals worldwide, sized 1920 □ 1200 pxl, on a 24" TFT monitor. An example is shown in Figure 2.

Measures

Measures included diagnostic performance and eye movements. First, diagnostic performance was assessed with participants' written diagnosis. Second, eye movements were recorded with a Tobii T60□L remote eye tracking system with a temporal resolution of 60 Hz; a fixation was defined with a velocity of 35 msec and a distance threshold of 35 pxl.

Results

In this section, we present the results of our analyses in two steps. First, we present pre-post differences on a performance level. Then, we present differences on an eye movement level.

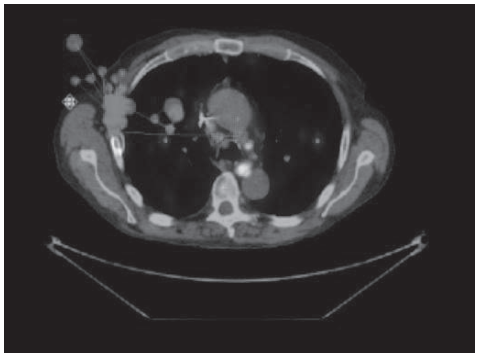

Figure 1. Eye Movement Modeling Example.

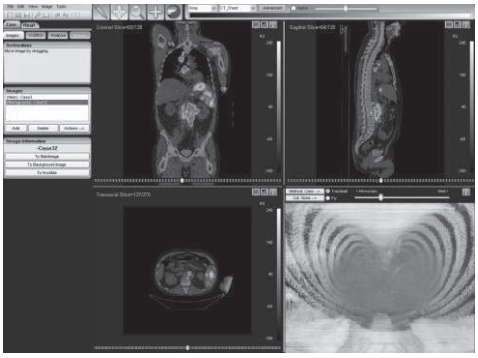

Figure 2. Example of PET/CT Patient Case.

Performance

Results of the performance measures showed considerable improvement in diagnostic accuracy after watching the eye movement modeling example, F (1, 17) = 40.95, p < .001, Cohen's d = 2.07. Also sensitivity F (1, 17) = 32.63, p < .001, Cohen's d = 1.66 and specificity F (1, 17) = 4.42, p < .05, Cohen's d = 0.59 improved. A more efficient attentional resource allocation may be the source of these improvements.

Eye movements

Results of the eye movement measures showed more fixations on task-relevant areas F (1, 17) = 56.30, p < .001, Cohen's d = 0.89 and fewer fixations on task-redundant areas F (1, 17) = 12.52, p < .01, Cohen's d = 0.99 after modeling. However, it should be noted that improvement in eye movements was not as drastic as improvement in performance.

Discussion

The aim of the study was to test whether technology-based gaze replay of experts can model diagnostic performance of novices in medical education. This research was inspired by previous findings in the literature, indicating that eye movement modeling examples to be detrimental for novice learning (Van Gog et al., 2009). In the present study, watching a technology-based gaze replay of experts had positive effects on novice performance and attentional resource allocation. The different findings on the effectiveness of gaze replay as a training tool between this and previous studies can be explained by the visual material used: the PET/CT visualizations that were utilized here had been considerably more complex in terms of their dimensionality and dynamics, which may have prevented the occurrence of a redundancy effect (Van Gog et al., 2009). In summary, it seems safe to conclude that expert gaze replay is an important resource in interpretation skills training. Although improvement in fixations was not as strong as expected, performance improvement was still considerable. Therefore, eye movement modeling examples can be used as a tool in medical education and training. Future research may extend the first steps reported here to the examination of gaze replays in other medical and non-medical arenas such as, among others, aviation, meteorology, or sports, as well as in the training of observation skills of classroom interaction in the teaching professions.

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