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Perceptual training: learning versus attentional shift

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Abstract. Prior research has demonstrated that perceptual training can improve the ability of healthcare trainees in identifying abnormalities on medical images, but it is unclear if the improved performance is due to learning or attentional shift—the diversion of perceptional resources away from other activities to a specified task. Our objective is to determine if research subject performance in perceiving the central venous catheter position on radiographs is improved after perceptional training and if improved performance is due to learning or an attentional shift. Forty-one physician assistant students were educated on the appropriate radiographic position of central venous catheters and then asked to evaluate the catheter position in two sets of radiographic cases. The experimental group was provided perceptional training between case sets one and two. The control group was not. Participants were asked to characterize central venous catheters for appropriate positioning (task of interest) and to assess radiographs for cardiomegaly (our marker for attentional shift). Our results demonstrated increased confidence in localization in the experimental group (p-value <0.001) but not in the control group (p-value $= 0.882$). The ability of subjects to locate the catheter tip significantly improved in both control and experimental groups. Both the experimental (p-value $= 0.007$) and control groups (p-value $= 0.001$) demonstrated equivalent decreased performance in assessing cardiomegaly; the difference between groups was not significant (p-value $= 0.234$). This suggests the performance improvement was secondary to learning not due to an attentional shift. © *2019 Society of Photo-Optical Instrumentation Engineers (SPIE)* [DOI: 10.1117/1.JMI.7.2.022407]

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1 Introduction

Radiology training involves the mentored evaluation of medical images during the clinical workday and education outside the reading room. Traditional radiology education outside the reading room in the form of books or didactic lectures focuses primarily on interpretation of findings, with little educational emphasis on the perception of findings.[1] However, recent studies have demonstrated that 60% to 80% of radiologic errors are attributable to perceptual errors rather than interpretive or cognitive errors.[2] In addition, recent studies demonstrate improved performance of trainees in identifying lesions after perceptual training.[3–6]

Prior research showed that providing perceptual training to study participants improved their ability to identify medically relevant abnormalities. Perceptual training has been applied to medical tasks including identification of pulmonary nodules[3] and central venous catheter evaluation.[4]

However, when assessing improvement in perceptual performance, an important confounding variable arises. Does the improved performance result from shifting attention to the task being trained and away from other interpretation activities? The phenomenon is known as attentional shift. Attentional shift has been described as "directing attention to a point increases the efficiency of processing of that point and includes inhibition to decrease attentional resources to unwanted or irrelevant inputs."[7] While a full review of attention in psychology is beyond the

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scope of this paper, we refer the interested reader to recent reviews that outline both the costs and benefits of deploying spatial attention.[7–9] A simple example of attentional shift would be talking on a mobile phone while driving. During a telephone call, attention may be significantly diverted toward the conversation and away from driving, making the driver more likely to be involved in a motor vehicle accident. Indeed, research suggests that talking on a mobile phone does result in an increased rate of accidents.[10] There is a large body of literature in cognitive psychology that demonstrates when spatial attention is focused on one region of space, detection is improved for this region and decreased in other regions.[11]

Thus, it is currently unclear whether the previously observed benefits associated with perceptual training may simply be due to an attentional shift toward the task in question. Attentional shift presupposes that people have a finite amount of resources of their brain dedicated to perception.[12] Providing attentional training on placement of central venous catheters likely increases the amount of attention paid to this structure in subsequent cases in the study. If trainees are taught to perceive a specific finding, they may demonstrate improved performance in identifying the finding due to attentional shift without actually improving their perceptual ability.[13,14] If performance is improved due to attentional shift, based on the cognitive literature, we should expect a concomitant decrease in performance on unrelated perceptual tasks.

Alternatively, improved performance may be due to the development of a new perceptual skill. If this is the case, we should expect that improved performance in identifying the finding will not be accompanied by decreased performance in untrained perceptual tasks. If training allows the radiologist to improve performance of a perceptual task, then performance on secondary, untrained tasks should be unaffected by the training.

During prior studies on perceptual training, subjects showed improved performance on the tasks related to the provided training.[3,15] For example, subjects provided with a search pattern for evaluation of central venous catheters showed improved performance at catheter characterization.[4] However, it is possible that the training caused participants to focus more of their mental energies on central venous catheter evaluation at the expense of other tasks and improved performance did not result from improving their perceptual skills.

Our objective is to determine whether the improvements in evaluating central line position are due to perceptual learning or to an attentional shift. For this study, participants were taught a search pattern for identifying central venous catheter position.[4] The ability to perceive cardiomegaly was used as a secondary untrained task to assess for attentional shift. The experimental group underwent perceptual training to identify central venous catheters between case sets, while the control group was provided a control task. We hypothesize that central line characterization will improve in the experimental group relative to the control group, while cardiomegaly assessment will be similar in both groups, suggesting no attentional shift has occurred.

2 Methods

2.1 *Subjects*

This study was approved by our institutional review board. All participants provided informed consent prior to participation. Forty-one physician assistant students voluntarily participated in a course designed to teach and assess perception of central venous catheters. The students had only limited prior exposure to radiology education.

2.2 *Study Environment*

The educational session was conducted using a simulated radiology workstation (SRW) program, RadSimP.[16] The monitors have a resolution of 1.8 megapixels, similar to the monitors used clinically by nonradiologists. The software displays digital imaging and communications in medicine (DICOM) files and allows windowing, leveling, and zooming. While the monitors were not DICOM grayscale standard display function calibrated, they were similar to the monitors the trainees use clinically.

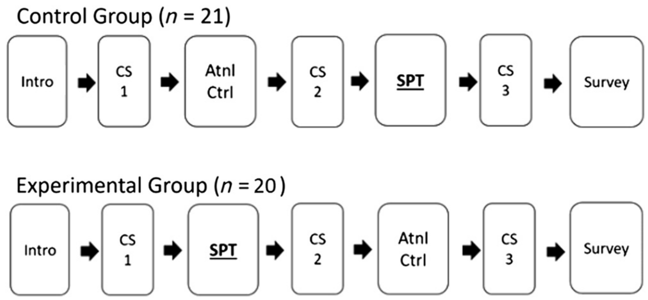

Fig. 1 Experimental design of our study. Intro, introductory materials; CS, case set; Atnl Ctrl, attentional control; SPT, simulated perceptional training; survey, poststudy survey.

2.3 *Study Design*

The research subjects were divided randomly into control ($n = 21$) and experimental ($n = 20$) groups. There were three simultaneous sessions of education, each containing members of the control and experimental groups. The experimental paradigm is summarized in Fig. 1. In the introductory materials, the research subjects were provided with training on using the study software for image display and recording subject responses. Subjects were also given information about basic chest radiography, appropriate central line positioning, and cardiomegaly assessment using digital PDF files. The educational files included both text and graphics. The trainees took ~5 to 10 min to complete this educational file. Cardiomegaly and line assessment were cued at the beginning of the first session for both control and experimental groups. However, for the experimental group, central line assessment was cued again after the first case set, while cardiomegaly was not cued again.

Both groups were tasked with evaluating a set of chest radiographs in which they were asked to perform the following tasks sequentially: identify the tip of the catheter, rate their confidence in their localization, rate the catheter as appropriately/inappropriately positioned, and rate whether or not cardiomegaly was present. Localization was accomplished via a mouse click. Mouse clicks within 5 mm of the catheter tip were marked as "correct." Confidence in localization was scored using a Likert-like response format with one being not at all confident and five being very confident. Assessment of appropriate catheter positioning was scaled from one to five, with one being definitely malpositioned and five being definitely appropriately positioned. Assessment of cardiomegaly was scaled from one to five, with one being definitely abnormal cardiac silhouette and five being definitely normal cardiac silhouette. All images contained a central catheter, half were adequately positioned and half were malpositioned. Of the 60 images, the cardiac silhouette was normal in 32 and enlarged (cardiomegaly) in 28. The distribution of normal cases, abnormal cases, and case difficulty was roughly equal across all case sets. Images were chosen to be interpretable given the expected level of participant experience and representative of normal and common abnormal central line positioning.

Each case set contained 20 chest radiographs. One image was displayed per case. Subjects had 20 min to complete each set of cases. The cases in each case set were the same for all subjects. No images were shown more than once. After the first case set, the experimental group received perceptual education on catheter tip assessment in the form of an electronic PDF file containing textual and graphical instructions, while the control group read a journal article on radiography for intensive care unit patients. An example of the perceptual education training is shown in Fig. 2. Perceptual training took about 10 min.

Both groups then evaluated another case set of 20 chest radiographs. Comparisons of change between case set 1 and case set 2 were used for analysis. To ensure that all participants received equal education, after case set 2, the experimental group received the attentional control article and the control group received perceptual education training. Following this second round of education, the trainees evaluated a third case set of 20 chest radiographs, which was not used for analysis.

After completing the third set of cases, subjects answered an eight-item questionnaire, shown in Table 2. Results were collected using a five-point scale: 1, strongly disagree to 5, strongly agree.

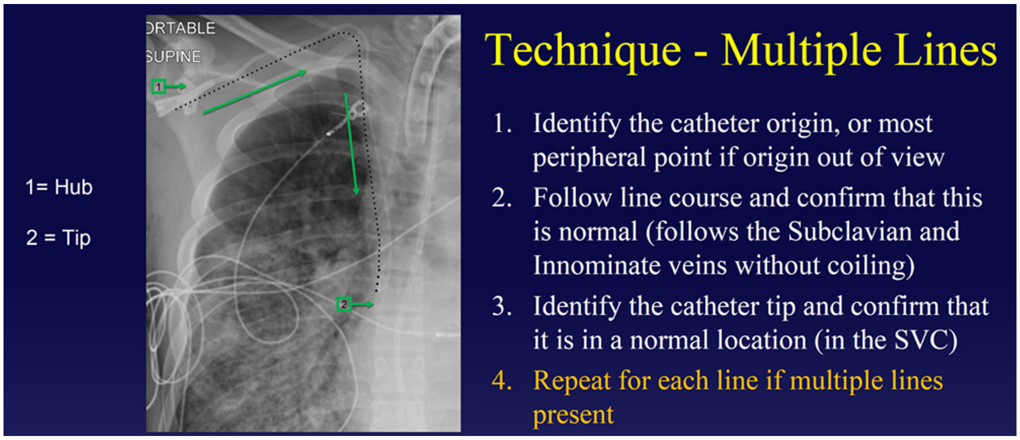

Fig. 2 Example of central venous catheter perception training.

2.4 *Statistics*

Localization receiver operator characteristic curve analysis (LROC) was used to compare performance between case set 1 and case set 2 in both groups. The mean area under the curve (AUC) was used as the figure of merit. Statistical significance for changes in mean AUC (Δ mean) was computed using the bootstrap with 1000 iterations. LROC analysis was used to compare accuracy of tip localization. Receiver operator characteristic curve analysis (ROC) was used for assessment of safe catheter positioning and assessment of cardiomegaly. Mean difference in confidence between case 1 and case 2 (Δ mean) was also compared and statistical significance was quantified using the bootstrap. The difference in performance between control and experimental groups, $\Delta\text{Diff} = \Delta$ mean control group $-$ Δ mean experimental group, was also computed for the statistics discussed above. The statistical significance of ΔDiff was quantified using the bootstrap. The analysis software was written by the authors in the Python programing language.

After the educational session, trainees were given surveys to evaluate their experience. Results are demonstrated graphically using frequency polygons. The statistical significance of questionnaire responses was quantified using the Wilcoxon signed-rank test.

3 Results

3.1 *Quantitative Catheter and Cardiomegaly Assessment*

Our results demonstrated that neither the control nor experimental group improved their performance in correct localization ($p = 0.320$, $p = 0.654$, respectively), both with high AUC on both case sets 1 and 2. Both the control and experimental groups demonstrated improved performance in assessing whether catheter positioning was adequate ($p = 0.010$, $p < 0.001$, respectively). The experimental group demonstrated increased confidence after training (mean difference

Table 1 Summary of statistics for correct localization of catheter tip mean AUC (CorLoc), assessment of safe catheter positioning AUC (SafePos), assessment of cardiomegaly AUC (CardMeg), and mean confidence in localization accuracy (ConfLoc). Ctrl, control group; Exp, experimental group; Δ mean, change in mean value between case sets 1 and 2; ΔDiff, Δ mean control group—Δ mean experimental group.

	Ctrl Δ mean	Ctrl *P*-value	Exp Δ mean	Exp *P*-value	ΔDiff *P*-value
CorLoc	0.014	0.32	−0.017	0.654	0.727
SafePos	0.062	0.01	0.1	<0.001	0.098
CardMeg	−0.041	0.007	−0.065	0.001	0.234
ConfLoc	−0.112	0.882	0.303	<0.001	0.001

0.303, $p < 0.001$). Conversely, the control group did not demonstrate increased confidence [mean difference (-0.112, $p = 0.882$)].

There was a statistically significant decrease in cardiomegaly assessment performance in both the control and experimental group. ΔAUC-heart-control $= -0.041$ (p-value $= 0.007$), ΔAUC-heart-experimenal $= -0.065$ (p-value $= 0.001$). The difference in ΔAUC-heart between control and experimental groups, ΔDiff, was 0.024, p-value $= 0.234$; the difference was equivalent across both groups and did not differ significantly. These results are summarized in Table 1 and graphically displayed in Fig. 3.

3.2 *Survey*

Surveys were provided to the trainees to assess their experience. Overall, survey data showed positive feedback for all questionnaire items with all p-values <0.001. Survey questions are shown in Table 2 and results are displayed graphically in Fig. 4.

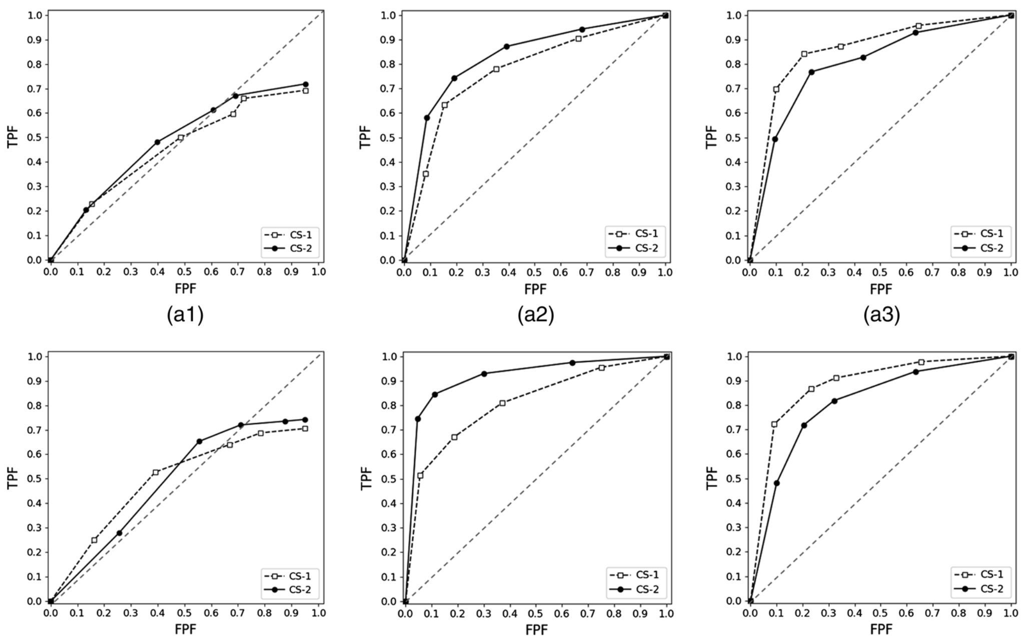

Fig. 3 ROC curves: A1: control group correct localization of catheter tip (CorLoc), A2: control group assessment of safe catheter positioning (SafePos), A3: control group assessment of cardiomegaly (CardMeg). B1: experimental group correct localization of catheter tip (CorLoc), B2: experimental group assessment of safe catheter positioning (SafePos), B3: experimental group assessment of cardiomegaly (CardMeg). The diagonal dashed line present in all figures indicates the chance line.

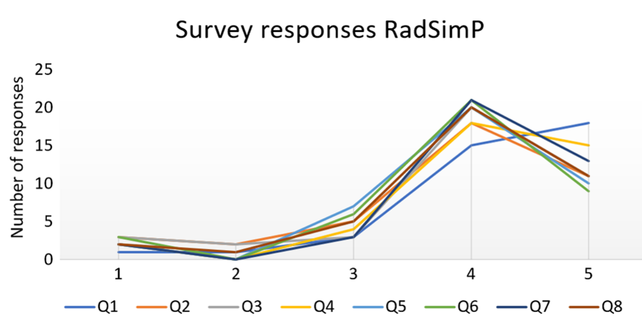

Fig. 4 Survey data demonstrating overall positive responses to survey questions (Q#). X-axis demonstrates Likert-like response scores from 1 to 5, with five representing a very positive response.

Table 2 List of survey questions.

Question 1	In my prior course work and self-study, I have not been shown specific eye movement patterns for evaluation of line/tube positioning on CXRs.
Question 2	The search pattern training was helpful for learning the skill needed to evaluate line/tube positioning on CXR.
Question 3	The search pattern training helped me feel more confident about my ability to identify line/tube positioning on CXR.
Question 4	Search pattern training for other medically relevant abnormalities would be a helpful way to learn about additional topics in radiology.
Question 5	The simulated radiology workstation (SRW) used for this study was helpful for learning the skills needed to evaluate line/tube positioning on CXR.
Question 6	Compared with conventional learning materials (including printed/electronic textbooks and case files), the SRW provided a more effective way to develop the skills needed to evaluate line/tube positioning on CXR.
Question 7	SRW would be a helpful way to learn about additional topics in radiology.
Question 8	Participation in this study was an overall positive experience.

4 Discussion

Our results demonstrated improved confidence in localization in the experimental group but not the control group. Additionally, improved performance was seen in assessing the adequacy of catheter position in both experimental and control groups.

Both the experimental and control groups demonstrated decreased performance in cardiomegaly assessment after intervention, with a similar magnitude of decrease that did not significantly differ between groups. Denote CVC characterization as task-C and heart/cardiomegaly assessment as task-H. If attentional shift after perceptual training for task-C had occurred, attentional shift theory predicts that performance on task-H relative to task-C would have worsened. As comparable performance was demonstrated on both task-H and task-C, there is no evidence to suggest that there was significant attentional shift.

If the improved performance in assessment for adequate catheter positioning in the experimental group was due solely to attention shift, then cardiomegaly performance would decrease more substantially in the experimental group relative to the control group. The observation that both groups demonstrated a decrease in cardiomegaly assessment of qualitatively similar magnitude suggests perceptual learning as the dominant factor in improvement, not attention shift. This is an encouraging result that points to the promise of simple interventions that may lead to improved performance on a trained task without hurting performance on other, untrained tasks. These results suggest that effective training interventions may simplify the complex task that clinicians face by helping them accomplish specific tasks more efficiently, thereby not incurring the costs associated with an attentional shift.

However, the decrease in cardiomegaly performance in both groups after intervention was an unexpected finding. We posit that assessing cardiomegaly may be a burdensome task to inexperienced chest imaging interpreters, and trainees may spend less time and attention resources to this task over time. It is also possible that the second case set consisted of radiographs in which cardiomegaly was more difficult to assess than in the first. Cases in the case sets were distributed randomly; however, an imbalance in difficulty could have occurred. Future endeavors could utilize analysis of the third case series to see how cardiomegaly assessment performance changed.

The experimental group demonstrated improved confidence in tip localization while the control group did not. While neither group demonstrated improved tip localization, improved confidence was shown in the experimental group relative to the control group. Overall, improved confidence is important for clinical decision making and for trainees in becoming independent practitioners.

This study had several limitations. One limitation is that we worked with physician assistant students during this protocol not radiologists. It is unclear how such a training paradigm would translate to individuals with greater domain knowledge and practical skill. Another limitation is that the entire study lasted only 2 h, and there is no data to suggest how long the effect of training will last.

In conclusion, there was improved confidence in catheter tip localization in the experimental group compared with the control group, and both experimental and control groups showed improved performance at characterizing catheters as appropriately positioned versus malpositioned. While performance on cardiomegaly assessment decreased, it decreased in both experimental and control groups, and there was no significant difference in cardiomegaly performance. This suggests that the improved performance was due to perceptual learning and not due to attentional shift. In addition, post-training survey results demonstrated that, subjectively, the trainees viewed their experience positively. These results provide a proof-of-concept demonstration that simple training protocols implemented to large groups of participants simultaneously can yield significant benefits for the task in question without adversely affecting performance of other tasks. Moreover, these results suggest that perceptual training may be a useful educational tool, and these training techniques may potentially be extended to other aspects of radiology. Areas in which further study would be helpful include long-term follow-up to assess for retention of education/training effect and testing this paradigm on radiologists.

Disclosures

No authors have a conflict of interest to disclose.

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