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Current Opinion in Psychology

Evaluation of strategies to train visual search performance in professional populations

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Visual search, the act of finding targets amongst distractors, is central to many professions with life-or-death implications including aviation security, radiology, lifeguarding, military, and more. As such, every effort should be taken to improve visual search performance. One potential path to improvement is to ensure that workforces are optimally trained. Broadly, there are three general components to train: (1) specific use of the machinery and user interface (i.e. ‘knobology’), (2) target and distractor identification, and (3) search strategy. The current review considers the cognitive psychology aspects of these three components; each is evaluated in light of short-term and long-term training goals, as well as profession-specific constraints.

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Current Opinion in Psychology 2019, **29**:113–118

This review comes from a themed issue on **Attention and perception**

Edited by **Sarah Shomstein, Andrew Leber** and **Joy Geng**

https://doi.org/10.1016/j.copsyc.2019.01.001

Visual search, the process of finding targets among distractors, is a multifaceted cognitive process that is both theoretically interesting and practically important (Figure 1). Visual search involves several cognitive abilities (e.g. perception, attention, decision making), and thus offers insight into various theoretical hypotheses. Practically, visual search is central to many professions, in which failure to find a target can be catastrophic, including aviation security, radiology, many military tasks, inspection positions, and lifeguarding (Table 1).

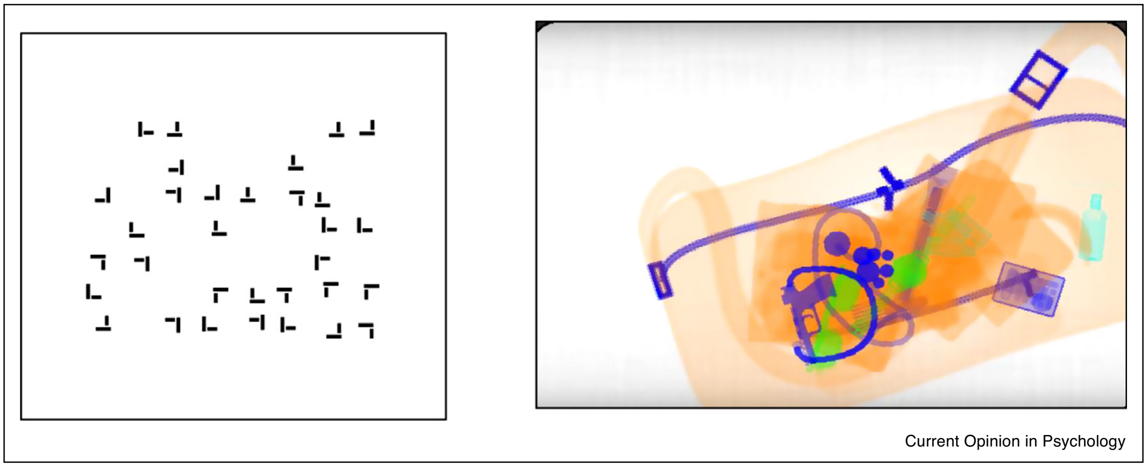
Given visual search's centrality to applied settings, it is vital to understand its underlying processes and potential ways to improve performance. Extensive prior research has examined the cognitive mechanisms at play [e.g. in Refs. [1–3], automaticity [4,5], aspects of search related to real-world tasks [e.g. in Refs. 6–8], and much more. The current review focuses on one particularly intriguing visual search issue—how to train workforces to improve visual search skills. We will primarily review how basic cognitive psychology research may be able to be leveraged to inform applied interests.

The current review will not focus on particular training programs of particular organizations or groups (e.g. medical image graduate programs, aviation security training protocols). This is done for a few reasons. First, while it is clear that existing programs are employed to train personnel, rarely are these programs evaluated and tested in a manner meant for a peer-review publication—the protocols are not designed for empirical investigation. Second, many of the protocols are intentionally not shared publicly (aviation security organizations do not share how they train their officers to find contraband), so there is limited data available to review. Finally, the goal here is to focus on the contribution of basic cognitive research toward the general field of visual search training.

Visual search training can broadly be divided into three components (Table 2): (1) ‘knobology’ —learning how to use the necessary equipment/technology, (2) object identification—learning what are and are not targets, and (3) search strategy—learning how to look for targets. Generally, knobology and object identification components have the potential to train a workforce on how to use the provided equipment and identify specific targets, while the search strategy component provides generalized training that can potentially transfer across professions and settings. Some situations may favor the more circumscribed nature of knobology and object identification (e.g. pathologists tasked with finding a specific set of targets using a specific set of tools) while other situations will benefit more from general search strategy training (e.g. aviation security officers tasked with finding an unknown array of threats in an undefined range of search arrays with frequently changing technology).

It is natural to compare the effectiveness of different training components, but it is important to ensure the comparisons are valid and aligned with the training goals. For example, a recent comparison of training protocols found that object identification training was more effective than strategy training [9••]. However, if the study participants had been given multiple days of training instead of one 90-min session [9••], it is conceivable that the harder-to-learn search strategy protocol could have become the more effective tool. That is, more complex

Figure 1



Sample visual search displays. Left is a typical search from academic research efforts and the right is an example of more complex arrays that professionals may engage with (right image is from *Airport Scanner* and reproduced with permission from Kedlin Company).

training procedures (like learning to use a new strategy) may require more time for the trainees to master before the benefits are realized. In line with this, in a non-training study, use of a particular search strategy—searching consistently from trial to trial—was found to be a better predictor of search accuracy for experienced than for early career professional aviation security officers [10]. This may be because the early career searchers were still learning the consistency strategy, which presented them with an added cognitive burden.

In the current review we will briefly discuss knobology and object identification training, then focus more extensively on search strategy training. We will discuss each with respect to potential short-term and long-term training goals from an applied perspective.

Visual search training component 1: 'knobology'

Nearly every workforce tasked with critical visual searches interacts with technology. As such, workforce performance is maximized when the employees are trained to best use the technology, including the different functions and controls of the imaging machines. For example, aviation security screeners use X-ray machines that allow for multiple viewpoints and various image filters (grayscale, highlighting metals only, etc.). For these features to aid target detection, the workforce must be trained on how to effectively switch between different viewpoints [11], what each image filter does, and when best to employ each. Otherwise, the presence of image enhancement options can actually deteriorate performance [12,13]. Beyond the technical knowledge of

Table 1

Example professions that rely on visual search with the relatively stability of their potential targets and environment and with the relative frequency of technological changes for the profession

Search Profession	Examples	Target nature	Environment	Technology changes
Checkpoint Security	Aviation, Border crossings, Building entrances	Highly variable	Variable	Frequent
Border Protection and Safety	Border crossing monitoring, Coast Guard search and rescue	Highly variable	Highly variable	Frequent
Medical Imaging	Radiology, Cytology, Pathology	Stable and Known	Stable	Frequent
Military searches	Checkpoints, Room clearing	Highly variable	Highly variable	Frequent
Product Inspection	Manufacturing plants, Product quality control check	Stable and Known	Stable	Frequent
Physical Inspection	Aircraft integrity	Stable and Known	Stable	Infrequent
Pest Control	Termite Inspection	Stable and Known	Stable	Infrequent
Lifeguarding	Pool/beach monitoring	Variable	Variable	Infrequent
Archeology	Fossil discovery	Stable and Known	Variable	Infrequent

Table 2

The three main components of professional searches that can be potentially be trained with parameters that may influence the short-term and long-term prospects of training

Training component	Time to master	Generalizes across technology/vendors	Generalizes across targets/environments
'Knobology'	Fast	No	Yes
Object identification	Medium	Questionable	No
Search strategy	Slow	Yes	Yes

features, it is also critical to train for human–computer interaction. Accurate use relies on the ability to trust but also question the technology at hand [e.g. in Ref. 14]. Thus, it is necessary to train for potential technology failures and their fixes [15•].

A hallmark of knobology training is its specificity to particular machines and protocols. From a short-term perspective where quick learning is needed, or in a relatively closed-system search environment (where new target types or new environments rarely occur), knobology training can be highly effective; for example, studies that have looked to train the use of electrocardiography (ECG) and ultrasound technology have found that brief training sessions (~2 hours) are sufficient to provide machine-naïve medical students and professionals with basic diagnostic skills [16,17]. However, there are drawbacks. First, retraining is necessary with each new vendor and technological advance. Second, the specific nature of the training does not promote generalized learning, so the potential for carryover to other tasks or stimuli is limited. In sum, knobology training is effective for the short-term goal of ensuring the workforce can operate their current technology, but the need to retrain with each change may limit the long-term payoff.

Visual search training component 2: object identification

Radiologists need to know the visual characteristics of cancerous nodules, aviation security officers need to know how guns, knives, and explosives appear in the X-ray image [18], and lifeguards need to know the signs of a distressed swimmer [19]. Some searches involve a relatively constrained target set (e.g. breast cancer detection), while others have novel and unknown targets in variable environments (e.g. aviation security). These latter cases with varied-targets pose a difficult challenge from an object identification perspective. Specific search templates aid search [20,21], so the more varied and dissimilar potential targets are, the more search performance may suffer [22,23].

Object identification training has taken a variety of forms, including training to identify targets in canonical and non-canonical orientations [24], under conditions of clutter [25], with occlusion or camouflage [26], and through learning the background environment [27]. Similar to knobology training, object identification training can be limited in transfer. For example, in a study where participants searched for four different knives in simulated X-ray images of bags over multiple training sessions [28], the ability to detect those four knives improved. However, when four new knives were introduced at the final testing, the performance improvement did not transfer to the novel, but similar, targets. Furthermore, much of the cognitive research on object identification has been done at 50% target prevalence [e.g. in Ref. 27], but this is not representative of many applied search settings. Instead, many professional searches involve looking for rare targets, and it is unclear how these training techniques would transfer [29].

If the goal is to train a workforce to identify a circumscribed set of known targets (e.g. cancerous nodules that are generally known and unchanging), object identification training can be immensely useful for both short-term and long-term periods. However, if the goal is to be able to identify any target, including new ones that the workforce has not been trained on (e.g. new contraband developed to sneak through airport security), object identification training will ultimately fall short.

Visual search training component 3: search strategy

While search strategy training arguably has the most potential for broad and long-term payoffs, it is also the most complicated. Moreover, the optimal strategy will vary with each searcher's goals and environment, leading to differential solutions. For example, a lifeguard searching for distressed swimmers on a bustling beach will likely have to adopt a different search strategy than an aircraft inspector looking for cracks on a plane's fuselage. Broadly, there are two steps of visual search that we will discuss in turn: 1) searching the array and 2) deciding if a target is present [30–32].

Training search strategy—where to fixate

In general, experts search differently than novices, as seen across a number of realms from chess [33] to driving [34,35]. One key distinction is that experts generally use more consistent and systematic scan paths than novices [8]. This promotes more efficient coverage of the search field, increasing the probability that a target will be fixated, while also decreasing cognitive load [36,37]. As such, several forms of search strategy training have focused on training novices to use systematic scan paths.

One method for training search strategy is to highlight probable regions of interest. For example, novice drivers are taught where to look for potential hazards in simulated scenarios [38,39]. Likewise, in radiology, training may involve using a list of anatomic structures to check in a consistent order [40,41,42•], or superimposing other radiologists' search patterns [43–45]. In addition to displaying an expert search path, evidence from Marines suggests that simply providing feedback that compares an individual's search path to that of an expert can help [46]. Inspection industries have sometimes taken a direct approach, training with a dynamic stimulus to promote searching in a consistent order such as across, down, and back across [47–49].

The most important outcome of training the workforce is to improve accuracy and/or efficiency. As such, the critical question is whether search strategy training can not only improve coverage of key areas, but also detection rates. Despite the widespread existence of training programs, it is difficult to adequately test the effectiveness and generalizability of any such program. With no set 'gold-standard' of search strategy training, different studies implement different training techniques. Thus, there are varied results, and it is difficult to draw comparative conclusions. There is some evidence in favor of detection improvements [38,39], but this is not always the case. Often times, the improvement in coverage does not necessarily translate to an improvement in target detection or sensitivity [42•], or it comes at the expense of a speed-accuracy tradeoff [43,44]. In the cognitive psychology literature, there have been several attempts to use eye-movement feedback to encourage a full-coverage search pattern, but these attempts have failed to improve target detection [50••,51••]. A likely explanation is that you can train someone to alter their search pattern, but if that search pattern is effortful, their attentional demands will be too high for search to be successful. That is, even if you get a person to fixate (i.e. directly look at) a target, they might still fail to identify it as a target. It is an open question whether more extensive training combined with eye-movement feedback could eventually produce positive benefits, but speed-accuracy tradeoffs must be considered.

Training search strategy—improving decision making

Successful visual search requires searchers to not only locate targets, but to also correctly determine what are targets and what are not. In radiology, this distinction has been delineated in three forms of search errors [52,53]: (1) scanning errors—not fixating the target, (2) recognition errors—fixating the target but not for a sufficient amount of time to successfully process the item's identity as a target, and (3) decision errors—fixating a target for a sufficient amount of time but incorrectly concluding that the item is not a target. The focus of this section is on training to reduce decision errors—those created by incorrect decisions despite all necessary information being available.

The decision component of search involves information extraction—searchers must pull the appropriate information from visual search before making their decision [e.g. in Ref. 54]. Experts generally extract information and make decisions more accurately and efficiently than novices [e.g. in Refs. 55–57]. In some cases, the differences in information extraction are reflected in search pattern differences; for example, novice drivers typically have longer fixations and less horizontal scanning than expert drivers [34,35]. Information extraction differences have also been observed via non-search pattern metrics; for example, although expert badminton players [56] and squash players [57] were found to extract information earlier and more efficiently than novices in an anticipatory task, there were no differences in their fixations. Similarly, expert soccer players had no consistent differences in fixations from novices but were more sensitive to peripheral information [58], again suggesting an advantage in information extraction.

Training the decision component has great promise, but it takes time. Systematic search patterns can be trained, but improvements may not materialize until decision making skills are also developed. While information extraction and decision making improve with experience, there is limited research to date on how to actively train these aspects of search. Although training search strategy should have the most generalizable and long-term benefit to the workforce, further research is needed to understand how best to implement the training and realize the greatest benefits.

Discussion and conclusion

The goal of the current review is to provide a brief overview of the pros and cons of various forms of visual search training as it applies to professional settings. Building on basic research principles, there may be ways to improve industry operations by helping a workforce perform more efficiently and/or effectively. Broadly, 'knobology' and object identification training are seemingly best suited for short-term goals when it is critical to quickly teach the workforce how to use the technology and what to look for. However, technology and potential targets can change and such specific training is not likely to transfer. As such, these methods provide short-term gains but may be costly in the long run. Alternatively, search strategy training seems best suited for long-term goals, where learning should generalize across realms and be resistant to many workplace changes, as it is rooted in cognitive principles of decision making and systematic search patterns. The downside, however, is that it takes the longest amount of time to learn, and there is no clear evidence yet pointing to the ideal training strategy.

Each professional visual search environment comes with its own constraints, and there is no 'one-size-fits-all' approach to search training. However, the cognitive psychology literature suggests that search strategy training will likely lead to the most robust benefits for each individual employee and for the organization. The easiest path to the quickest wins in learning is to use circumscribed methods that are highly specific to the search task. However, it is important to consider both short-term and long-term goals when training a workforce for professional search. While training for long-term benefits on a short time scale is the ideal in applied realms, effective and lasting training often takes time and should be carefully designed.

Conflict of interest statement

M.R. Kramer and C.L. Porfido have no conflicts of interest to declare. S.R. Mitroff is the Chief Science Officer of Kedlin Screening International—a small business that uses software solutions to help improve security screening operations. The company is currently focused on issues related to pre-hire assessments and current workforce assessments, but may explore training in the future. None of the work presented here is related to the company, but it may be possible that the company could indirectly benefit from some of the research suggestions laid out here if future research were to prove fruitful.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. Eckstein MP: **Visual search: a retrospective**. *J Vis* 2011, **11**:14.

2. Nakayama K, Martini P: **Situating visual search**. *Vis Res* 2011, **51**:1526-1537.

3. Wolfe JM: **Guided search 4.0: current progress with a model of visual search**. In *Integrated Models of Cognitive Systems.* Edited by Gray W. New York: Oxford; 2007:99-119.

4. Schneider W, Shiffrin RM: **Controlled and automatic human information processing: I. Detection, search, and attention**. *Psychol Rev* 1977, **84**:1.

5. Shiffrin RM, Schneider W: **Controlled and automatic human information processing: II. Perceptual learning, automatic attending and a general theory**. *Psychol Rev* 1977, **84**:127.

6. Krupinski EA: **Improving patient care through medical image perception research**. *Policy Insights Behav Brain Sci* 2015, **2**:74-80 http://dx.doi.org/10.1177/2372732215600451.

7. Mitroff SR, Biggs AT, Cain MS: **Multiple-target visual search errors: overview and implications for airport security**. *Policy Insights Behav Brain Sci* 2015, **2**:121-128.

8. Wetter OE: **Imaging in airport security: past, present, future, and the link to forensic and clinical radiology**. *J Forensic Radiol Imaging* 2013, **1**:152-160.

9. •• Guznov S, Matthews G, Warm JS, Pfahler M: **Training techniques for visual search in complex task environments**. *Hum Factors* 2017, **59**:1139-1152.

This study compared the effectiveness of several training techniques for a simulated unmanned aerial vehicle environment and found that, while benefits of both search strategy and object identification training were found, the greatest benefits were found with object identification training. This study highlights the potential value of object identification training, but also shows that longer training might be necessary for the full benefits of search strategy training to be realized.

10. Biggs AT, Cain MS, Clark K, Darling EF, Mitroff SR: **Assessing visual search performance differences between Transportation Security Administration Officers and nonprofessional visual searchers**. *Vis Cogn* 2013, **21**:330-352.

11. Michel S, Schwaninger A: **Human-machine interaction in x-ray screening**. In . October *Proceedings of the 43rd IEEE International Carnahan Conference on Security Technology*. 2009.

12. Michel S, Koller S, Ruh M, Schwaninger A: **The effect of image enhancement functions on X-ray detection performance**. *Proceedings of the 4th International Aviation Security Technology Symposium* 2006:434-439.

13. Klock BA: **Test and evaluation report for X-ray detection of threats using different X-ray functions**. In *IEEE ICCST Proceedings*. 2005:182-184.

14. Drew T, Cunningham C, Wolfe JM: **When and why might a computer-aided detection (CAD) system interfere with visual search? An eye-tracking study**. *Acad Radiol* 2012, **19**:1260-1267.

15. • Sauer J, Chavaillaz A, Wastell D: **Experience of automation failures in training: effects on trust, automation bias, complacency, and performance**. *Ergonomics* 2016, **59**:767-780.

This paper highlights that an operator's trust in automation and performance depends on the technology failures that they are exposed to during training. This emphasizes the importance of proper and comprehensive training on how to best interact with the technology available.

16. Chalumeau-Lemoine L, Baudel JL, Das V, Arrivé L, Noblinski B, Guidet B, Maury E: **Results of short-term training of naive physicians in focused general ultrasonography in an intensive-care unit**. *Intensive Care Med* 2009, **35**:1767-1771.

17. Vignon P, Dugard A, Abraham J, Belcour D, Gondran G, Pepino F, Gastinne H: **Focused training for goal-oriented hand-held echocardiography performed by noncardiologist residents in the intensive care unit**. *Intensive Care Med* 2007, **33**:1795-1799.

18. Halbherr T, Schwaninger A, Budgell GR, Wales A: **Airport security screener competency: a cross-sectional and longitudinal analysis**. *Int J Aviat Psychol* 2013, **23**:113-129.

19. Lanagan-Leitzel LK, Skow E, Moore CM: **Great expectations: perceptual challenges of visual surveillance in lifeguarding**. *Appl Cogn Psychol* 2015, **29**:425-435.

20. Bravo MJ, Farid H: **The specificity of the search template**. *J Vis* 2009, **9**:34.

21. Malcolm GL, Henderson JM: **The effects of target template specificity on visual search in real-world scenes: evidence from eye movements**. *J Vis* 2009, **9**:8.

22. Menneer T, Barrett DJ, Phillips L, Donnelly N, Cave KR: **Costs in searching for two targets: dividing search across target types could improve airport security screening**. *Appl Cogn Psychol* 2007, **21**:915-932.

23. Menneer T, Cave KR, Donnelly N: **The cost of search for multiple targets: effects of practice and target similarity**. *J Exp Psychol Appl* 2009, **15**:125.

24. Koller SM, Hardmeier D, Michel S, Schwaninger A: **Investigating training, transfer and viewpoint effects resulting from recurrent CBT of X-ray image interpretation**. *J Transp Secur* 2008, **1**:81-106.

25. Beck MR, Trenchard M, van Lamsweerde A, Goldstein RR, Lohrenz M: **Searching in clutter: visual attention strategies of expert pilots**. In *Proceedings of the Human Factors and Ergonomic Society*. 2012:1411-1415.

26. Neider MB, Ang CW, Voss MW, Carbonari R, Kramer AF: **Training and transfer of training in rapid visual search for camouflaged targets**. *PLoS One* 2013, **8**:e83885.

27. Chen X, Hegdé J: **Learning to break camouflage by learning the background**. *Psychol Sci* 2012, **23**.

28. McCarley JS, Kramer AF, Wickens CD, Vidoni ED, Boot WR: **Visual skills in airport-security screening**. *Psychol Sci* 2004, **15**:302-306.

29. Breast Cancer Surveillance Consortium: *Cancer Rate (per 1,000 Examinations) and Cancer Detection Rate (per 1000 Examinations) for 1,960,150 Screening Mammography Examinations From 2002 to 2006 by Age*. 2009 . Retrieved from *http://breastscreening.cancer.gov/data/performance/screening/2009/rateage.html*.

30. Drury CG: **Inspection of sheet materials—model and data**. *Hum Factors* 1975, **17**:257-265.

31. Spitz G, Drury CG: **Inspection of sheet materials—test of model predictions**. *Hum Factors* 1978, **20**:521-528.

32. Ghylin KM, Drury CG, Schwaninger A: **Two-component model of security inspection: application and findings**. *16th World Congress of Ergonomics*. 2011.

33. Reingold E, Sheridan H: **Eye movements and visual expertise in chess and medicine**. In *Oxford Handbook on Eye Movements.* Edited by Gilchrist ID, Everling S. Liversedge: Oxford University Press; 2011:528-550.

34. Crundall DE, Underwood G: **Effects of experience and processing demands on visual information acquisition in drivers**. *Ergonomics* 1998, **41**:448-458.

35. Crundall D, Chapman P, Phelps N, Underwood G: **Eye movements and hazard perception in police pursuit and emergency response driving**. *J Exp Psychol Appl* 2003, **9**: 163-174.

36. Clark K, Fleck MS, Mitroff SR: **Enhanced change detection performance reveals improved strategy use in avid action video game players**. *Acta Psychol* 2011, **136**:67-72.

37. Leff DR, James DR, Orihuela-Espina F, Kwok KW, Sun LW, Mylonas G *et al.*: **The impact of expert visual guidance on trainee visual search strategy, visual attention and motor skills**. *Front Hum Neurosci* 2015, **9**:526.

38. Pradhan AK, Pollatsek A, Knodler M, Fisher DL: **Can younger drivers be trained to scan for information that will reduce their risk in roadway traffic scenarios that are hard to identify as hazardous?** *Ergonomics* 2009, **52**:657-673.

39. Chapman P, Underwood G, Roberts K: **Visual search patterns in trained and untrained novice drivers**. *Transp Res F Traffic Psychol Behav* 2002, **5**:157-167.

40. Auffermann WF, Henry TS, Little BP, Tigges S, Tridandapani S: **Simulation for teaching and assessment of nodule perception on chest radiography in nonradiology health care trainees**. *J Am Coll Radiol* 2015, **12**:1215-1222.

41. Auffermann WF, Little BP, Tridandapani S: **Teaching search patterns to medical trainees in an educational laboratory to improve perception of pulmonary nodules**. *J Med Imaging* 2015, **3**:011006.

42. • Kok EM, Jarodzka H, de Bruin ABH, BinAmir HAN, Robben SGF, van Merrienboer JJG: **Systematic viewing in radiology: seeing more, missing less?** *Adv Health Sci Educ: Theory Pract* 2016, **21**:189-205.

This paper shows that, while experts have a more systematic search pattern and perform better than students, there were no performance improvements found in students that underwent a systematic search training. This highlights the challenges in finding effective training strategies, as the practices of the experienced may be too effortful to be effective for the less experienced.

43. Litchfield D, Ball LJ, Donovan T, Manning DJ, Crawford T: *Learning from Others: Effects of Viewing Another Person's Eye Movements While Searching for Chest Nodules. In Medical Imaging 2008: Image Perception, Observer Performance, and Technology Assessment*. International Society for Optics and Photonics; 2008 March, p. 691715.

44. Litchfield D, Ball LJ, Donovan T, Manning DJ, Crawford T: **Viewing another person's eye movements improves identification of pulmonary nodules in chest x-ray inspection**. *J Exp Psychol Appl* 2010, **16**:251.

45. Vitak SA, Ingram JE, Duchowski AT, Ellis S, Gramopadhye AK: **Gaze-augmented think-aloud as an aid to learning**. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. 2012, May:2991-3000:. ACM.

46. Carroll M, Kokini C, Moss J: **Training effectiveness of eye tracking-based feedback at improving visual search skills**. *Int J Learn Technol* 2013, **8**:147-168.

47. Nickles GM, Melloy BJ, Gramopadhye AK: **A comparison of three levels of training designed to promote systematic search behavior in visual inspection**. *Int J Ind Ergon* 2003, **32**:331-339.

48. Nickles GM, Sacrez V, Gramopadhye AK: **Can we train humans to be systematic inspectors?** *Proceedings of the Human Factors and Ergonomics Society Annual Meeting (Vol. 42, No. 16, pp. 1165-1169)* 1998, October.

49. Koenig SC, Liebhold GMY, Gramopadhye AK: **Training for systematic search using a job aid**. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*. 1998:1457-1461.

50. •• Drew T, Williams LH: **Simple eye-movement feedback during visual search is not helpful**. *Cogn Res Princ Implic* 2017, **2**:44.

The authors sought to use eye-movement feedback to improve target detection and efficiency, but did not find any reliable improvements in performance. This paper highlights the challenges with search strategy training—there is much to be learned about how to improve search performance beyond improving coverage.

51. •• Peltier C, Becker MW: **Eye movement feedback fails to improve visual search performance**. *Cogn Res Princ Implic* 2017, **2**:47.

Similar to Drew & Williams [50••], here the authors attempted to use a variety of eye-movement feedback methods to improve search performance in rare target search. Again, they failed to find reliable improvements in performance with this training method. While seemingly intuitive that increasing coverage would improve search performance, failures in decision making seem to remain.

52. Berbaum KS, Franken EA Jr, Dorfman DD, Miller EM, Krupinski EA, Kreinbring K *et al.*: **Cause of satisfaction of search effects in contrast studies of the abdomen**. *Acad Radiol* 1996, **3**:815-826.

53. Kundel HL, Nodine CF, Carmody D: **Visual scanning, pattern recognition and decision-making in pulmonary nodule detection**. *Invest Radiol* 1978, **13**:175-181.

54. Recarte MA, Nunes LM: **Mental workload while driving: effects on visual search, discrimination, and decision making**. *J Exp Psychol Appl* 2003, **9**:119.

55. Goulet C, Bard C, Fleury M: **Expertise differences in preparing to return a tennis serve: a visual information processing approach**. *J Sport Exerc Psychol* 1989, **11**:382-398.

56. Abernethy B, Russell DG: **The relationship between expertise and visual search strategy in a racquet sport**. *Hum Mov Sci* 1987, **6**:283-319.

57. Abernethy B: **Expertise, visual-search, and information pick-up in squash**. *Perception* 1990, **19**:63-77.

58. Williams AM, Davids K: **Visual search strategy, selective attention, and expertise in soccer**. *Res Q Exerc Sport* 1998, **69**:111-128.