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Exploring Visual Maturity: A First Look at Eye Behavior in Train Traffic Control

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Abstract
The present study investigated differences in visual expertise across levels of proficiency in train traffic control during a simulated scenario. Eye tracking metrics reported in a meta-analysis study on visual expertise were used as a theoretical base. The aim of the study was to investigate whether the same results found in the meta-study could be obtained in the less predictable and dynamic work environment of train traffic control. Results of the study indicate that eye behavior seemed to correlate with years of experience also in a more naturalistic setting, but it did not correlate with expert ranking by instructors or a post-hoc measure of proactivity in task performance. A discussion is provided in which a delineation of experience and expertise is postulated considering the differences between eye movement behavior and cognitive aspects of problem-solving.

Keywords
Visual expertise, eye tracking, experience, train traffic control, rail human factors

Introduction
Eye tracking studies of visual expertise have repeatedly shown that experts exert a significantly different pattern of eye movements than novices. Studies have been performed with, for example, chess players (Charness et al., 2001), artists (Kristjanson & Antes, 1989), nurses (Currie et al., 2018), map users (Ooms et al., 2014), and a wide variety of sports professionals. Within human factors, studies have been performed with pilots (Schriver et al., 2008), drivers (Chapman & Underwood, 1998), and control room operators of air traffic (van Meeuwen et al., 2014), road traffic (Starke et al., 2017), and petrochemical processes (Koffskey et al., 2014). The aim of this study is to investigate whether the same pattern of eye movement behavior of experts as observed in previous studies can be elicited in the train traffic control domain during realistic working tasks.

Regarding train traffic control, it has been shown in explorative field studies that train traffic controllers' eye behavior change over time as they continuously switch between the history and the planning horizons in the digital tools and paper graphs they use. They do this to manage both monitoring of all trains in a dedicated geographical region, and the execution of a specific train at a particular meeting point (Axelsson & Jansson, 2018). So far, the domain of train traffic control has not been explored in studies of visual expertise and eye behavior. Sturman et al. (2019) conducted a study on cue-utilization during sustained attention in a rail control task using eye-tracking data. However, they used a control task with a simplified rail control display. Further, they explicitly demanded no previous exposure to rail control operations from their participants. Without connections to representative work tasks, and with undergraduate students as participants, their study does not qualify in the area of visual expertise. In fact, few studies present in the literature make use of dynamic stimuli and experiments reported in these studies are often performed in stable environments with a lack of representativeness of the everyday environment of the participating experts. One exception is the study by Itoh et al. (2000) who conducted a study for eye-movement analysis of track monitoring patterns of night train operators and investigated the effects of geographical knowledge and fatigue. However, their results do not generalize to the area of train traffic control since their study was conducted on engineers in a night train. This study explores eye behavior in a train traffic control simulator to achieve a more naturalistic and dynamic environment in which to study experts' eye behavior.

Visual Expertise

Gegenfurtner et al. (2011) conducted a meta-study using 73 data collections sourced from 65 different articles on eye movement behavior across levels of expertise present in the literature up until December 2010. The authors used three theories to formulate hypotheses for the study: (1) the theory of long-term working memory (Ericsson & Kintsch, 1995), (2) the information-reduction hypothesis (Haider & Frensch, 1999), and (3) the holistic model of image perception (Kundel et al., 2007). Results showed that experts have superior parafoveal processing and selective attention allocation as evidenced through shorter durations of fixations, a higher rate of fixations on task relevant areas, and a lower rate of fixations on irrelevant areas. In addition, experts had shorter time-on-target for fixating on task-relevant areas and wider saccades overall. Experts, therefore, have a more targeted gaze behavior when searching for relevant cues in the environment for solving problems or making informed decisions.

Aim of This Study

This study investigates whether eye movement behavior correlates with level of expertise in train traffic control. As mentioned above, studies on expert eye movements have repeatedly shown that eye movements differ across levels of expertise. Therefore, the question is whether a similar pattern of eye behavior across levels of expertise can be found in train traffic controllers. Preliminary results from field studies show that more experienced controllers have better foresight and proactive abilities than less experienced controllers (Axelsson & Jansson, 2018) and the question we raise here is if these differences in both perceptual and cognitive strategies among train traffic controllers manifest themselves in differences in eye movement behaviors. The aim of this study is to explore whether the results on visual expertise in the study by Gegenfurtner et al. (2011) generalize to data from a naturalistic task in train traffic control.

Research Question

Can the differences in eye movement behavior across levels of expertise found in many other domains also be found in a naturalistic train traffic control task?

To answer this question, the results found in the meta-analysis of expert eye behavior presented by Gegenfurtner et al. (2011) will serve as the theoretical base of the present study. As acknowledged by the authors of the meta-analysis, effect sizes in visual expertise are often small, which means that one would need many participants to expect statistical significance. Unfortunately, there are practical constraints on the ability to recruit many participants for a study of experts in train traffic control, because the potential pool of participants is small and difficult to access. Therefore, the present study shall be seen as a first explorative and descriptive case study, investigating the relation between eye behavior and expertise in train traffic control.

Method

Participants

Eleven (M_{age} = 35.27; 5 female) qualified train traffic controllers were recruited from a traffic control center of the Swedish Transport Administration. Recruitment was conducted with the help of on-site instructors to ensure a wide span of experience levels among the participants based on years in the profession (min_{years} = 0.67; max_{years} = 34; M_{years} = 8.28).

Materials

The experiment was performed in the training facility of the train traffic control center in which the participants worked. The training traffic simulator in the facility was used in the experiment. A 30-minute train traffic scenario was designed for the simulation in collaboration with an on-site instructor. The scenario was based on existing timetable data of a busy weekday between the hours 12:30 and 13:00. Apart from the task of general traffic oversight, the scenario also included 5 interspersed tasks that required special attention and protocol:

1. 12:32 Shunting
2. 12:37 Signal fault
3. 12:39 Route protection I
4. 12:49 Route protection II
5. 12:54 Wrong track request

The workstation had 3 monitors displaying the control area, as well as a keyboard and a mouse for interaction with the system (see Figure 1). The participants had all their necessary equipment at hand for performing the train traffic control task: pens, pencil, eraser, ruler, and a headset. They were provided with paper graphs covering 1.5 hours of train schedules before the start of the traffic scenario and 1 hour after the end of the scenario. They were also provided with forms necessary to perform the task: (a) a form for allowing traffic to pass a faulty signal and (b) a train dispatcher ledger for keeping track of route protections.

Measurements

As in the meta-study by Gegenfurtner et al. (2011), the independent variable was expertise, approximated by years of experience. As an independent measure of work performance, participants were also ranked by two independent instructors who work closely with them. The eye-tracking metrics used as dependent variables were as follows:

1. Number of fixations on relevant areas
2. Dwell time on relevant areas, in seconds
3. Time to first fixation on relevant task area after task onset, in seconds
4. Saccade lengths, in pixels

Procedure

Each session was conducted with one participant at a time. The simulator was operated manually by an instructor. The instructor placed necessary calls for requests to the participant and answered any calls from the participant via the facility’s internal telephone system. Before the session started, the participants were given a short introduction and asked to provide their birth year and years of experience as a train traffic controller.

Equipment

During the scenario, participants wore a set of Tobii Glasses 2 that captured their eye movements at a sampling rate of 50 Hz. Corrective lenses were used with individuals who would normally wear glasses to provide corrected-to-normal vision during data collection. All areas of interest (highlighted in blue in Figure 1) were defined, and eye movement metrics were calculated in Tobii Pro Lab-Analyzer (v1.92.13555) using the Tobii I-VT fixation filter (Tobii Technology, 2012). Statistical analyses were then performed using R (v3.4.4).

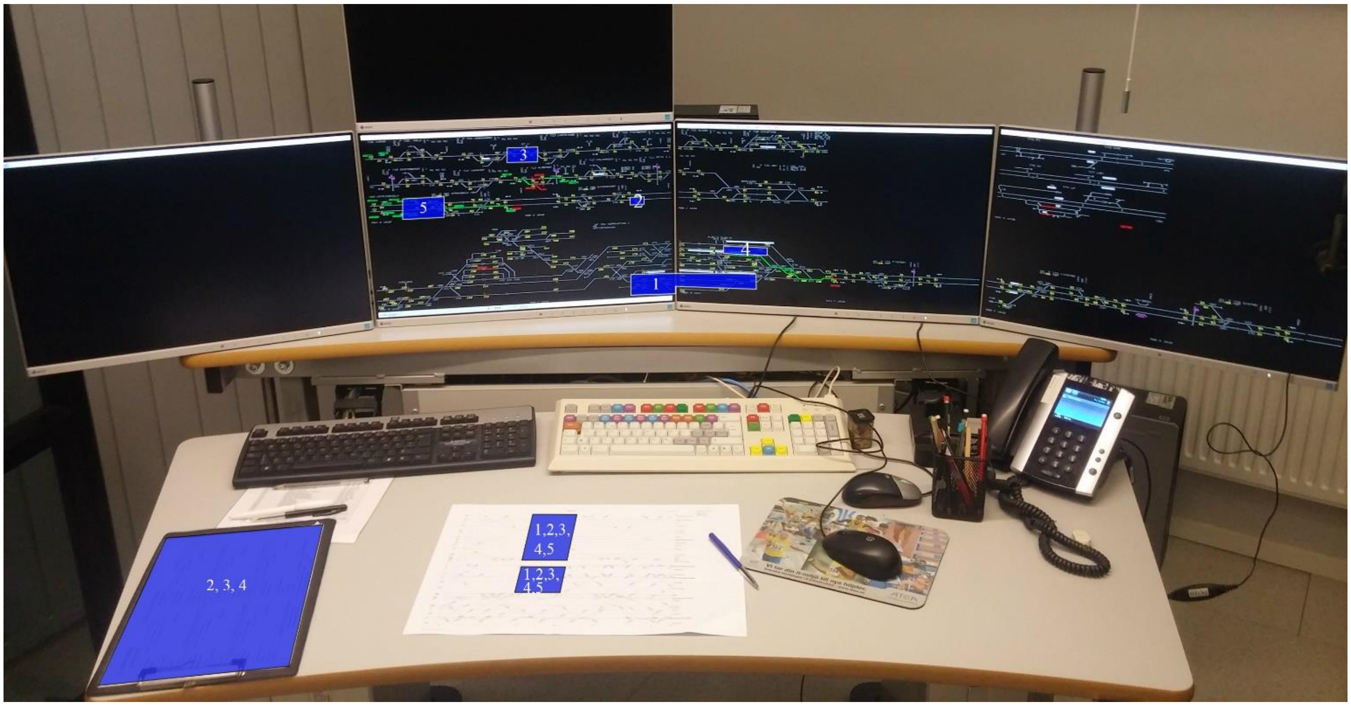

Figure 1. Workstation of the train traffic simulator used in the study with areas of interest for each task highlighted in blue

Analysis and Results

As a measure of how well the participants generally perform in their everyday work, two instructors working closely with the participants were asked to rank them from the least to the most expert train traffic controller. Each participant was therefore assigned a rank number from 1 to 11. The inter-rater reliability between the two instructors was strong at r_τ = 0.71. An analysis between the mean value of the two rankings and years of experience revealed only a moderate positive correlation (*r* = 0.42). This positive correlation indicates that train traffic controllers with more years of experience were generally rated higher. The correlation is only moderate which also indicates that the ranking represents something other than merely years of experience.

Mean, standard deviation, point biserial correlations reported in the meta study of Gegenfurtner et al. (2011), and correlation coefficients with confidence intervals of the analyses of the eye tracking metrics across years of experience and rank are provided in Table 1. Spearman's rank correlation analyses were carried out with the mean ranking of the two instructors while Pearson's product moment correlation analyses were used with years of experience. A matrix of scatter plots of all correlations analyzed is presented in Figure 2.

Table 1. Eye movement metrics descriptive statistics and correlation coefficients across various measures of expertise with 95 % confidence interval in brackets

Metric	*M*	*SD*	r_{pb}[1]	Experience (*r*)	Rank Mean (*ρ*)	Proactivity (*r*)
Relevant fixations	0.22	0.09	0.53	0.30 [-0.37, 0.76]	-0.15 [-0.69, 0.49]	-0.01 [-0.60, 0.60]
Relevant dwell time	0.25	0.12	0.27	0.34 [-0.32, 0.78]	-0.35 [-0.80, 0.33]	0.04 [-0.58, 0.62]
Time to first fixation	17.70	18.10	-0.31	-0.38 [-0.80, 0.28]	-0.34 [-0.79, 0.35]	0.05 [-0.57, 0.63]
Saccade length	519.19	103.85	0.30	-0.36 [-0.79, 0.31]	0.30 [-0.38, 0.77]	-0.55 [-0.86, 0.08]

[1] *Reported by Gegenfurtner et al. (2011). r = Pearson's product moment correlation, ρ = Spearman's rank correlation*

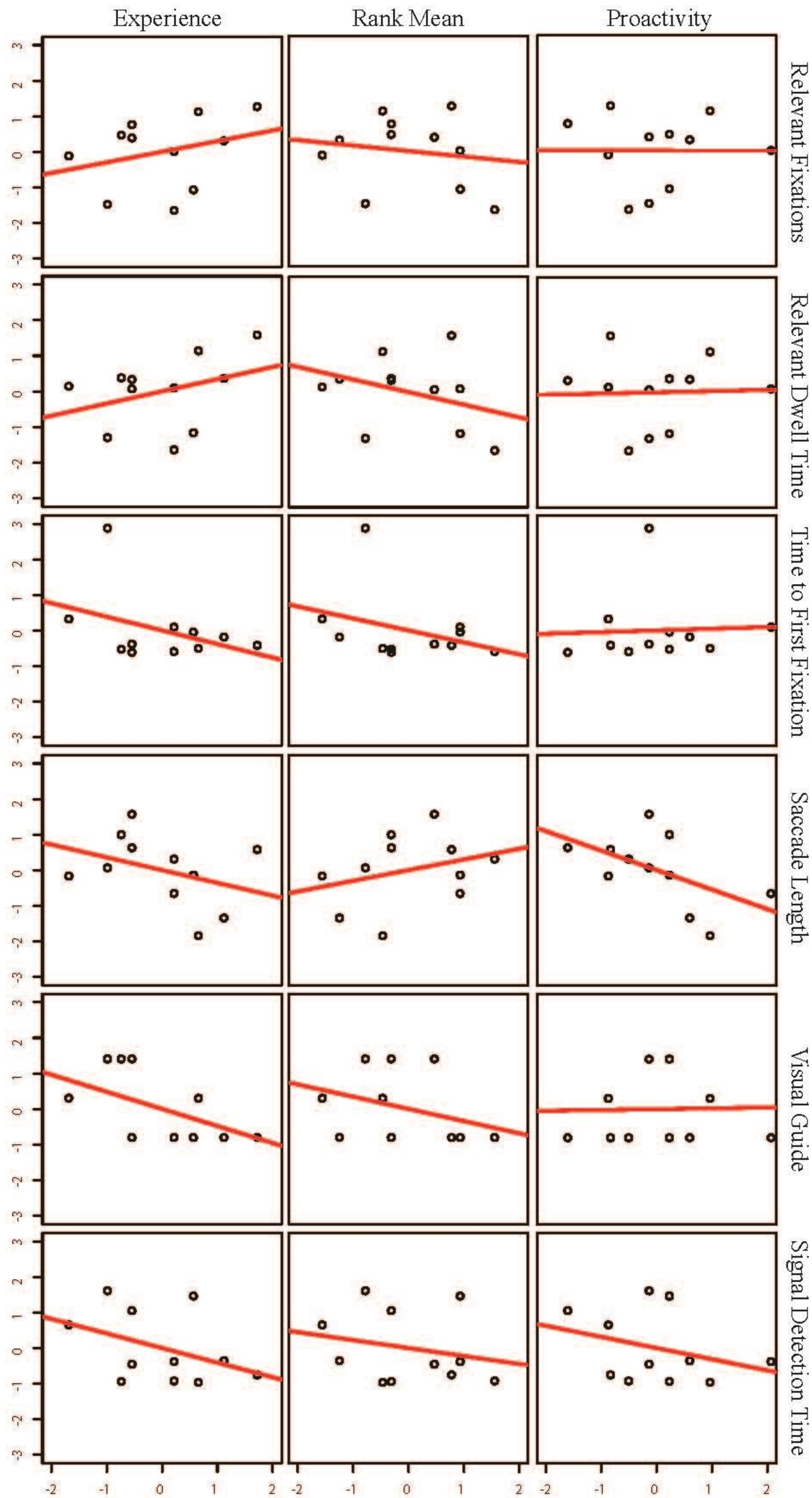

Figure 2. Scatter plot matrix of all correlations between eye movement metrics and measures of expertise

Regarding fixations and dwell time on relevant areas as well as time to first fixation, correlations show the same relationship to years of experience as the results of Gegenfurtner et al. (2011). Participants who have worked longer as train traffic controllers fixate faster, more, and longer on relevant areas than the less experienced. However, in this investigation, when it comes to saccade lengths, less experienced controllers exert longer saccades than the more experienced.

Regarding instructor rankings, the results are almost diametrical to those of established correlations between eye behavior and level of expertise. Only time to first fixation shows the same direction in correlations with ranking; that is, the higher a participant was ranked, the shorter time it took for the participant to fixate on a relevant area.

Exploring Task Performance

Because of the diametrical results between years of experience and instructor rankings, an attempt was made to investigate whether performance of the tasks could be measured and analyzed against the eye tracking metrics.

Time-on-Task

One way to evaluate task performance is to use time-on-task as a measure. However, the tasks used in the present study were everyday tasks that the traffic controllers are drilled in performing, and these tasks are also heavily regulated by procedures and protocols. Therefore, there was no expectation of finding differences large enough in time-on-task between participants to be of interest. This notion was supported by a correlation analysis of performance times across years of experience ($r = 0.04$). Assessing quality is a better way to explore task performance.

Proactivity

As discussed in the introduction of this paper, one crucial aspect of expert train traffic control is the ability to work proactively. Potential proactive actions were elicited from several situations throughout the scenario. Participants were then awarded one point for each proactive action and a minus point for any late action performed. For some situations, an on-time point of zero was recorded. The requirement for each action is stated in Table 2.

The mean of the proactivity action scores served as a central score between −1 and 1. A reasonable assumption is that the metric is not linear, which means that its explanatory value would increase as the metric approaches 1. Testing years of experience against the proactivity measure as an exponent of Euler's number resulted in a weak positive correlation with years of experience ($r = 0.26$). Pearson product-moment correlation analyses were carried out with the eye tracking metrics and the proactivity metric (Proactivity column in Table 1). As with years of experience, proactivity displayed a correlation with saccade length in a direction opposite of what was found by Gegenfurtner et al. (2011). The measure showed no correlations with other eye tracking metrics.

Domain Specific Metrics of Visual Maturity

In this sample of experts, the years of experience seem to best mimic the results reported by Gegenfurtner et al. (2011). It can be argued that years of experience more indicative of visual expertise than the other two measures of expertise. Therefore, these results might indicate that years of being exposed to the train traffic control environment promote certain eye movement behaviors.

A study of the video material showed that several of the train traffic controllers used visual guides when working with the paper graph of the planned train schedule. To map time and location of trains, controllers sometimes use the provided ruler or their fingers to keep track of the time axis across train routes (Andreasson et al, 2019). Others do not use guides and are comfortable with just glancing at the time axis and make quick judgements (see Figure 3). Another aspect is the signal fault task. Signals are represented in the system by right (▷) and left (◁) pointing triangles depending on the permitted direction of travel. These symbols are light grey against a black background; whenever a fault occurs in the signal, the symbol turns white (see Figure 4). This change is very subtle, and detection of a faulty signal demands a trained eye.

Table 2. Basis for the proactivity score

Task	Action	Proactive (1p)	On-Time (0p)	Late (-1p)
Planning	Meeting on single track	Prepare meeting 12:35 or earlier	Prepare meeting before 12:50	Prepare meeting after 12:50
Shunting	Prepare route	Before crossing train has passed and before the requesting engine has halted at stop signal	Before crossing train has passed	After crossing train has passed
Route Protection	Initiate 1st protection	Finish documentation and system settings before end of call	Document or perform settings after end of call	Document and perform settings after end of call
Route Protection	Initiate 2nd protection	— " —	— " —	— " —
Route Protection	Terminate 1st protection	— " —	— " —	— " —
Signal Fault	Configure switch	Before train reaches faulty signal	During phone call with driver	After phone call finishes
Signal Fault	Prepare form 21	Before phone call with driver	N/A	After phone call has been initiated
Signal Fault	Call train on-route	Before it reaches the route of the faulty signal	Once it reaches the route of the faulty signal	The train calls because it has reached the faulty signal
Signal Fault	Reroute next train	Prepare wrong track route for the next train to avoid the faulty signal	N/A	Prepare route through the faulty signal
Wrong Track Request	Prepare route	Prepare route before end of session	N/A	Route not prepared at end of session

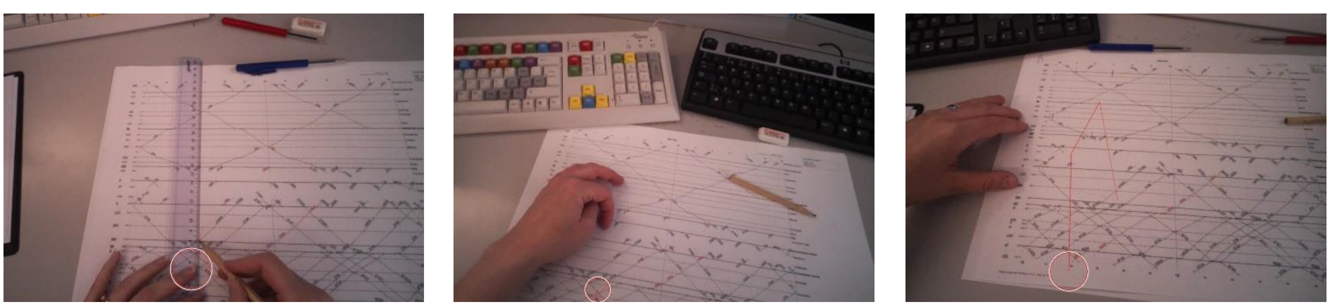

Figure 3. Examples of guides used to determine time and location in the train traffic graph, from left to right: ruler, hand, and no guide

Table 3. Correlation analyses of alternative measures of visual maturity with 95 % confidence interval in brackets

Measure	Experience	Rank Mean	Proactivity
Visual guides	$\tau = -0.48[-0.77, -0.19]$	$\tau = -0.34[-0.71, 0.03]$	$\tau = 0.02[-0.38, 0.43]$
Detect signal	$r = -0.41[-0.81, 0.25]$	$\rho = -0.22[-0.73, 0.44]$	$r = -0.31[-0.77, 0.35]$

τ = Kendall's *tau-b, r* = Pearson's product moment correlation*, ρ* = Spearman's rank correlation

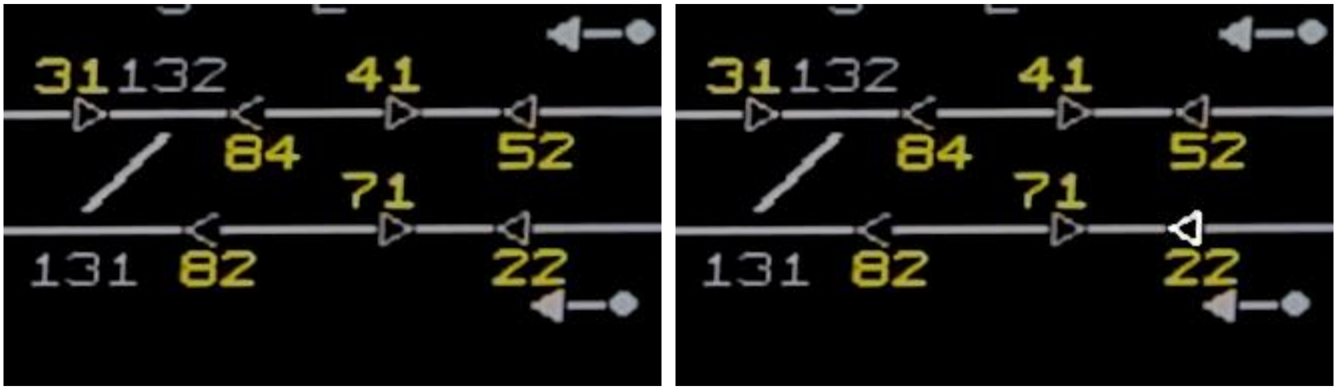

Figure 4. System representation of a normal signal (left) and a faulty signal (right)

Related to information seeking in this environment, behaviors that might change over time are the use of visual guides and the detection of a faulty signal. Therefore, if there are differences in these behaviors across levels of proficiency in train traffic controllers, then a correlation between measures of such behaviors and measures of expertise should exist. Considering that years of experience had stronger correlations with the eye tracking metrics than the other two metrics of expertise, one can postulate that a similar pattern should emerge in an analysis with measures of visual guide use and signal fault detection.

A manual video analysis was conducted on the material to identify the visual guides used in conjunction with the paper graph. Use of a ruler was considered more of a visual guide than using hands which in turn was considered more of a visual guide than simply glancing at time indicators. Regarding signal fault detection, the time was measured between the switch from normal signal to faulty and the first fixation before actions were taken. The reason for not simply using the first fixation on the signal after onset was so it could be determined if the fault were identified by the controller.

Due to ties in the visual guide measure, Kendall's taub correlation analyses were carried with visual guide and years of experience, rank mean, and proactivity. With the time to detect signal, experience, and proactivity, Pearson's product moment correlation analyses were conducted; with rank mean, Spearman's rank correlation was used (see Table 3).

As predicted, years of experience displayed a negative correlation with visual guide use that was stronger than the correlations with the other two measures of expertise. Similarly, signal fault detection had a stronger correlation with years of experience than did the other two measures of expertise.

Discussion

The present study investigated differences in visual expertise across levels of proficiency in train traffic control during a simulated train traffic scenario containing five different control tasks. As a theoretical basis, the study made use of eye tracking metrics reported in a meta-analysis of 65 studies of visual expertise conducted by Gegenfurtner et al. (2011). The aim of the study was to investigate whether the same results found in the meta-study could be obtained in the less controlled and dynamic work environment of train traffic control. Three out of the four collected metrics were in line with the results of previous studies. Train traffic controllers with more years of experience did fixate more on relevant areas, they also spent more time fixating on more-relevant areas and were quicker at locating these relevant areas visually. However, results pertaining to other measures of expertise did not elicit the same relations to traditional metrics of eye movement behavior in this naturalistic setting. These differences deserve special attention, and we invite readers to make their own interpretations of the results we have provided here. As a start, we provide a first discussion on the difference between experience and expertise.

It is important to clarify what is meant by expertise in the domain under investigation. Experts are rarely general problem solvers but are individuals who perform exceptionally well on tasks which they have deliberately practiced (Ericsson & Lehman, 1996). When it comes to expertise, it is crucial to understand that years of experience does not necessarily correlate with expert performance. Campitelli and Gobet (2011) reviewed studies on chess expertise with a focus on deliberate practice and found strong evidence that abundant deliberate practice is necessary but not sufficient to achieve high level of expert performance. Fisher (1991) denotes the difference between experience and expertise in the sense that the two are somewhat different aspects. He contrasts an experienced individual with a novice and an expert with a naïve individual. Experience says nothing about the quality of the knowledge acquired by the individual, only that they have been "exposed" to the knowledge domain. Thus, a naïve individual can still be highly experienced. Expertise, on the other hand requires deliberate and guided practice of high quality; therefore, the nature of the experience is crucial.

Study Differences from Traditional Studies of Visual Expertise

The present study is unique in that it differs from more traditional studies of visual expertise regarding (1) study environment, (2) study participants, (3) nature of task, and (4) stimuli.

Study Environment

Eye behavior is highly dependent on both task and stimuli. An important aspect to note here is that most previous studies make use of static stimuli, often presented in a controlled environment. The present study made use of a simulator and a more naturalistic and dynamic task. Controlled experiments are usually carried out with static stimuli on computer screens in a delimited area with stimuli being presented one at a time and using remote eye trackers. Normally, one would expect experts to have larger saccades as an indication of more directed gaze behavior toward relevant cues in the presented stimuli. However, this study was conducted in an environment with a higher degree of representativeness to the target domain, which means that the stimuli were not only digital renditions on screen but also physical stimuli, such as paper graphs, forms, and other paraphernalia used to perform the control tasks. Therefore, the resulting larger saccades by less proficient controllers are not necessarily surprising.

The study environment in Figure 1 depicts how scheduled trains are presented on a paper graph lying on the workstation table. Controllers who are inexperienced in the environment will shift more between the graph and the screens, resulting in longer saccade movements on average in the environment. This result is also supported by the results that less experienced controllers make use of their hands or rulers to guide their visual systems to the correct spot in the graph. More proficient controllers would be confident in the control tasks and would therefore not need to consult the paper graphs as often. Directed gaze behavior of more experienced traffic controllers was, however, indicated by shorter times to fixate on relevant areas. More experienced controllers do not need to shift between the screen and graph and also need less support of visual guides to ensure that correct actions are taken at the right time. Regarding detection of a signal fault in the system, all three measures of expertise indicated that fast detection is related to level of expertise. In addition, use of visual guides in this study have the strongest correlation with years of experience than any other of the measure of information seeking behavior. This finding may suggest that these two environment-specific measures of visual maturity could have a stronger correlation with proficiency than more traditional eye tracking metrics.

What these results indicate is the importance of taking the study environment into consideration when applying eye tracking methodologies. A metric indicating expertise in one domain might not hold for another.

Study Participants

The participants in the present study are unique in the sense that they are not representative of a normal population. Train traffic controllers are selected for their positions through rigorous psychological, cognitive, and physical health tests to ensure that they can handle stress and maintain multiple goals. Traditionally, novices in studies of expertise are either naïve individuals or students who have no actual work experience with the tasks they perform. However, using such study participants is not possible in a domain in which one must be familiar with the system to perform the required task. This meant that even the least experienced individuals in the present study handled the situations as expected by adhering to protocol and completing all the tasks without any major incidents. Furthermore, according to one of the instructors involved in the experiment, some of the train traffic controllers have no ambition of becoming experts. They simply want to do their job and show no sign of active engagement over and above learning protocol. This concern was raised in discussions with instructors on how to rate the controllers.

Even if years of experience did correlate with eye behavior as indicated by previous studies, ranking and the proactivity measure did not show the same correlations with traditional eye tracking metrics. These results mimic the non-linear relationship between experience and expertise as argued by Fisher (1991). Proactivity, as measured in the present study, did not reveal any relationship to the use of visual guides, indicating that visual maturity may have little to do with the problem-solving of train traffic control tasks. It does, however, relate to how high controllers are ranked by the instructors. Thus, use of visual guides by controllers could be an indication of proficiency to an instructor. The use of visual guides is a very conspicuous behavior that instructors can take note of and use in their judgements. Years of experience, however, has the strongest correlation with use of visual guides, indicating that this domain-specific metric might be consider as a way of identifying controllers with developed visual maturity in the task of train traffic control. The results of the present study also indicate that more proactive participants have overall shorter saccades, suggesting that, whether experienced or not, they most likely internalize the task better than individuals who are less proactive.

What this discussion points to is that years of experience might not always serve well as a proxy for expertise. In vocational domains, not all individuals aim to become an expert, and researchers in these domains might have to make use of other measures of expertise.

Nature of Task and Its Stimuli

Most studies on expert eye movements deal with highly visual tasks, such as performing surgery, reading image scans of patients, or playing chess or certain sports. In these areas, tasks are highly dependent on visual expertise. Train traffic control does certainly include visual tasks; however, the controller's problem solving involves problem solving, which is more of a cognitive task. Furthermore, the systems used in traffic control today are very low in resolution when it comes to representing trains in real-time. This makes the study environment different from other human factors-related experiments of visual expertise. For example, in studies with vehicle drivers or airplane pilots, these individuals navigate directly in an environment with low changeover times between action and feedback and high visual demands. Furthermore, tasks in more traditional studies of visual expertise are usually well defined in the participant's instructions and often repeated multiple times. In the present study, none of the participants knew what would happen during the scenario, and tasks were sometimes overlapping with one another. There was no stated time limit for the incorporated tasks apart from the fact that the whole scenario ended at 13:00 of the simulated time. The tasks were, on the other hand, quite normal everyday tasks that all participants could handle. The rationale here was to make the scenario as close as possible to a natural work scenario. This decision can explain the diametrical results that years-long experience give compared with the other two measures of expertise. Ability to control train traffic is not as contingent upon visual maturity as it is on more cognitive capabilities of reasoning and problem-solving.

The train traffic control system is highly stylized and abstract; designers of the system have constructed a high-level interface in which important elements have been represented with unambiguous symbols. In other domains, detection of certain stimuli is learned through trial and error. In chess, weak positions are stimuli consisting of seemingly ambiguous groupings of squares and pieces, and they become obvious only after laborious processes of thousands of chess games. In medicine, cancer cells that a trained eye can detect are lumps of organic matter that can take many forms. In driving or flying, one must learn the relation between surrounding environmental cues and potential outcomes, making decisions in split-seconds. The train traffic control room is in this sense a much more sheltered environment for the detection of visual cues. Furthermore, as a guide, controllers have graphs telling them what time they can expect oncoming traffic in a given location. Therefore, from a perceptual standpoint, the task is less demanding because perceptual processes are supported by the system, leaving more resources for cognitive processing for problem-solving. However, the identified use of visual guides on the paper graphs attests to a development over time in visual matureness.

Experience Versus Expertise

These four differences lead us to a discussion on the differences between experience and expertise both generally and for the continuation of studies on visual expertise specifically. One finding in this study was that the measure of years of experience was more related to findings of other studies than were instructor rankings and proactive control behavior. One possible reason for the seemingly paradoxical results could be that the work of controlling train traffic is more of a cognitive than perceptual task. Eye tracking provides a researcher with a trace of a process but captures little of the actual cognitive process behind task performance. Therefore, years of experience here is more a measure of visual maturity, or a maturity of perceiving stimuli from a particular environment. In fact, some of the more experienced train traffic controllers were rated on the lower end of the ranking scale by the instructors and some performed worse on the proactivity score than less experienced controllers. In the tasks of the present study, it is likely that learning to know where to look is not as difficult as the overall task of providing control of train traffic that is up to standards; that is, to uphold a smooth flow with utilization of the capacity and without unnecessary interruptions. In the present study, no completely naïve individuals were recruited as they would not be able to perform any of the required tasks. Other studies have indeed found differences between novices, intermediates, and experts. However, these are often studies in which visual proficiency lies at the heart of the actual tasks and where visual expertise is a crucial aspect of the work.

Limitations

Any of the four differences in the present study discussed above can be seen as a strength of the present study by increasing validity, but the differences can also be argued to be limitations of the experiment by decreasing reliability. Another caveat is the lack of statistical power in the study. The use of only 11 participants in an eye tracking study will always be a serious limitation because of the generally low effect sizes found in most studies in visual expertise (Gegenfurtner et al., 2011). One of the strongest correlations found in the present study was between use of visual guides and years of experience. Still, on an alpha level of 5%, provided that the effect is real, this result is expected to be found in only 60 % of cases using 11 participants. Unfortunately, such effect sizes are to be expected in studies with highly experienced individuals. These experts are scarce, and because the present study makes use of individuals that are bound by work schedules and tight budgets, low effect sizes will be a limitation in future studies of visual expertise in train traffic control.

Further Studies

In the present study, the task of re-routing trains around signal fault was one of the proactive behaviors that more proficient train traffic controllers exhibited. Many similar situations could be identified to design a more challenging scenario and thereby produce a stronger delineation between levels of proficiency. Also, more intense train traffic scenarios, such as high disturbance on a train route, could be incorporated to increase cognitive load and force controllers to be more proactive and work more methodically to resolve situations.

Conclusion

The present study found results that are in line with previous studies in that train traffic controllers recruited in a naturalistic problem-solving task fixated more and longer on task-relevant areas and were also quicker to locate these areas if they had more years of experience. However, opposite to other study results, more experienced participants had shorter overall saccades during task performance, a result attributed to the specific environment and task domain of the study. Regarding other measures of expertise, the results were not as clear. Rankings from instructors were diametrical to the results of years of experience, and only saccade lengths and time to first fixation showed the same correlations with proactivity and ranking, respectively, as years of experience did. Traditional measures of eye movement behavior are highly abstracted and do not necessarily take into consideration the study of participants' everyday environment. Looking at whether participants made use of visual guides to help them perform the tasks and measuring the time it took them to identify a faulty signal in the system showed good promise as measures of visual maturity in the task domain. These results call for more studies of visual expertise in naturalistic settings and that such studies take other measures of expertise from the domain into consideration. What can be concluded from the present study is that higher levels of exposure to a particular environment will result in visual maturity within that environment but do not guarantee quality of performance in solving task-related problems when these tasks are not primarily visual in nature. It can be helpful to work toward delineation between visual expertise and domain-specific expertise. But, in the end, the most promising result presented is that years of experience seem to be indicative of improved information seeking behavior. Years-long observation in a particular environment fosters visual maturity of the environment's stimuli. We acknowledge that the present paper is speculative in nature, but we believe that it gives food for thought for researchers who would like to explore different measures of expertise in general, and visual maturity in particular.

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Authors' Declarations

The authors declare that there are no personal or financial conflicts of interest regarding the research in this article.

The authors declare that they conducted the research reported in this article in accordance with the Ethical Principles of the Journal of Expertise.

The authors declare that they are not able to make the dataset publicly available but are able to provide it upon request.

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