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The practical part of train driver education: experience, expectations, and possibilities

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Abstract

Objectives: The internship period of the Swedish train driver education was examined in terms of which types of situations can be sufficiently encountered in order to develop expertise to handle them safely and efficiently, and to quantify and specify the gap in expertise between expert and novice drivers in terms of risk of error and time efficiency. Focuswas on special cases (i.e., situations that occur rarely but may cause severe accidents if not handled correctly and efficiently).

Methodology: Data on which situations and special cases a driver's student can be expected to experience during the internship period were collected via a web-based questionnaire. Also, ratings of expectations on novice and expert drivers were obtained from train driver educators, employers, and instructors with the purpose of comparing the expectations with the novices practical experience.

Results and conclusions: The main results suggest that many special cases are generally insufficiently practiced during the internship and therefore should be practiced in simulators; that both experienced and novice drivers prioritize safety over efficiency; and that expectations on novice drivers are realistic considering their limited professional expertise.

Keywords: Train driver, Expertise, Train simulation, Practical training, Education methods, Practical skills, Profession development

1 Introduction

Train drivers are responsible for safe and efficient transportation of large numbers of passengers and goods. Usually, the working task is monotonous, however suddenly an incorrect signal or level-cross signal occurs and demands instant reaction. Errors can have devastating consequences regarding both human lives and damages to infrastructure, and driver actions are crucial for avoiding accidents [3, 11]. Dangerous situations can occur any working day and drivers need to be educated to handle them correctly. The aim of this study was to examine to what extent Swedish train drivers are trained for various situations, which knowledge gaps the drivers may have, and suggest ways to bridge this gap.

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Although the profession has in some ways changed with the introduction of different train control systems, and the development is moving towards a more supervisory role, the driver still must keep full awareness to be able to handle special cases safe and efficient [5, 23]. According to Dhillon [7] many railway accidents across the world are related to human performance, and on the same topic, it has been shown that even if technical improvements have led to a decrease in accidents, the proportion of accidents caused by human factors has not [20]. With further automation, complex and potentially dangerous situations will still arise, demanding knowledgeable and experienced drivers to make the right decisions.

Among crucial driver abilities, sustained attention has been suggested as the most important one [11]. Mistakes are associated with monotonous train driving [10] and disinhibited drivers [16]. Verbal communication errors have also been highlighted as an important risk factor [26, 27] as well as complex collaboration with the technology [13, 19]. Factors associated with a safer driving behavior are occupational calling [22] and practical training [18, 21]. The demands of the train driver depend on the context, such as country-specific regulations and working with freight or passenger trains [24]. Still, all drivers must be trained for many hazardous situations that may arise during their career.

The motive for the present study was that how often certain types of safety–critical situations occur during train driving, and consequently during practical training, could not be found in the literature. We argue that this information is crucial since training should focus on acquiring expertise required to decrease risks associated with special cases. This paper therefore presents a survey study on occurrence of specific situations during education, as well as experts' estimates of difference in skill between experts and novices in these specific situations.

The purpose was to examine the internship period of the train driver education to identify situations that are sufficiently and insufficiently encountered, respectively, to develop expertise. The research questions were accordingly formulated as follows. Firstly, how often during their internship do situations occur, which if handled incorrectly may cause delays or accidents? Secondly, how high are the expectations on an average novice train driver, as compared to expectations on an average experienced driver? The combined results will indicate situations that may require additional practice.

2 Background

To facilitate the understanding of the purpose and methods of this paper, this section includes background on theory of learning and on the Swedish train driver education.

2.1 Theory of learning

To be able to make progress and reflection, decisions in a particular situation are based on experience from similar situations, Knowledge of familiarity [14]. This is in line with the Dreyfus five-stage model describing stepwise development from novice to expert, which is widely accepted and has been used to describe and explain the behavior within several professions [6, 8, 9, 31].

In this model, sufficient practical training is required to develop into the next step. The novice knows the theory, however, needs necessary practical experience to become more flexible [4, 8]. With sufficient practical experience, better decisions can be made in similar situations (advanced beginner), yet not in unfamiliar situations [8]. During the last three steps (competent, proficient and expert), the experience leads to a holistic view of the profession, which means that rational and well-balanced decisions can be made also in new situations and contexts [8, 15].

The main difference between competent and expert is that the expert makes better decisions when the situation is more complex [12] and according to Dreyfus, when a new situation arises, the expert's decision-making is based on intuition while the competent uses a conscious analytical approach [8].

2.2 Swedish train driver education

Basic train driver education in Sweden is commonly carried out within the framework of the Swedish National Agency for Higher Vocational Education. The education period is 44–60 weeks of which the internship is 20–22 weeks (about 500 h). The internship is accomplished in real traffic under supervision of experienced drivers. The education is extensive, to prepare for employment at any of Sweden's approximately 40 train operators in freight- and passenger traffic. For specific knowledge requirements, an additional company-specific education is performed at the employer. Situations to be included in the practical part of the basic or the company-specific education are not specified by regulations [30]. Thus, the knowledge of novice train drivers may vary considerably.

3 Method

3.1 Occurrences during internship

In order to examine how often during internship situations occur, a first questionnaire was distributed to professional, now employed, train drivers. The train operators distributed an email cover letter stating the purpose of the study to their train-driver employees, including a link to a web-based and anonymous questionnaire that was open for about three weeks. The questionnaire included 43 situations and each respondent was asked how many times each situation had occurred during the last year. The first author of this article is an experienced train driver and instructor, employed as a teacher at a basic train driver education in Sweden. He consulted two other experienced train drivers and instructors in the process of selecting the 43 situations. All three instructors have experience from both freight and passenger trains. The selection was made with the aim of including a wide range of situations that a Swedish train driver could encounter. Many are special cases (situations that occurs only when something goes wrong), but also basics to be performed everyday by train drivers at some of the potential employers (e.g. *Driving on different types of rail* *traffic management systems* or *Different types of shunting*). Each included situation is expected to be handled correctly according to the rule book, and an error can lead to delays, incidents, or accidents. Each situation may occur regardless of if the driver drives freight or passenger trains, although some are more likely to occur for freight-train drivers, mainly because freight trains more often operate outside of main lines. However, none of the 43 situations is more likely to occur for a passenger-train driver than for a freight-train driver.

The train-driver education includes around 500 h of internship, until recently regulated by The Swedish Transport Agency [2] but is now more of a guideline for the educators. The 500 h is approximately one third of the annual working hours for the average respondent (90% of a full-time job). Therefore, for a representative presentation in this paper, the frequencies given by the train drivers were multiplied by 0.3 in order to correspond with the average internship for students. The 43 situations translated into English are presented in "Appendix A". The main motive for collecting data from professional train drivers instead of from students was that some of the situations are more likely to occur during certain periods of the year, and since each class of students has their internship during shorter periods of the year, the risk is that the results would be skewed (i.e., not representative of a whole year with all periodic fluctuations). The students follow a professional train driver's operational schedule during the internship, hence the results should be an unbiased representation of occurrences during internship.

3.2 Likelihood of incident or accident, and representativeness of situations

A second web-based questionnaire was addressed to 18 instructors to measure the criticality of each of the 43 situations. The instructors were asked to rate the likelihood that erroneous handling by a novice driver leads to an incident or accident, on a six-point scale graded from 0 (not likely at all) to 6 (very likely). Further, the instructors were asked to rate the representativeness of the 43 situations on a six-point scale ranging between 0 (not representative at all) to 6 (very representative).

3.3 Expectations on a novice train driver

A third questionnaire was designed to answer how high expectations on an average novice train driver are, as compared to expectations on an average experienced driver. This questionnaire was included for two reasons. Firstly, to find out how expectations on the two driver groups differ across a set of driving scenarios with varying complexity and severity. Secondly, to compare the Dreyfus [8] model with the experts' expectations on train drivers at different levels of expertise. The questionnaire was directed at educators who were active or recently had been active teachers on a basic education for train drivers. All were trained instructors and former or still active train drivers (most were still active). The questionnaire was also aimed at instructors, security officers or educational managers at the train operators, most of whom were still active drivers, the remainder former drivers. The email cover letter included a description of the purpose of the study and a link to the web-based questionnaire which was open for about two weeks.

The questions covered expectations on a novice driver with a diploma but who has not yet undergone the company-specific training, compared to an average experienced driver who has been employed for at least ten years. The measures were *amount of assistance needed* (minutes), *risk of error decisions* (percent), and *total time needed* (minutes). Assistance was defined as anything from a telephone call to searching for a solution through various written regulations and manuals. Risk of errors was defined as the mean risk of errors that (1) cause delays, and that (2) may lead to vehicle damage, incidents, or accidents ("Appendix B"). An accident results in injured people or damaged property, whilst an incident means an event that under different circumstances could have led to an accident.

The six scenarios that were assessed are of different complexity and severity, three simpler and three more complex (see "Appendix B"). The simpler scenarios contained fewer maneuvers to be performed and are expected to last for a shorter time. The scenarios were developed in collaboration with experienced instructors and teachers and are representative examples of simpler as well as more complex scenarios that may occur for a train driver. All six scenarios contain one or several of the 43 situations from the train driver's questionnaire, which together with contextual circumstances creates the scenario to be assessed. For example, Scenario 1 consists of only one situation (*Major balise transmission failure inside an operational zone*) and Scenario 3 of two situations (*ATP failure during train movement; Driven without ATC in an ATC-equipped area*), which together with the contextual circumstances provides the described scenario ("Appendix B").

Comparisons between expectations on experienced versus novice drivers in the six scenarios were made by testing effects of Scenario (the six scenarios) and Experience (experienced, novice) in a 6×2 repeated-measures analysis of variance. Main effects of Experience and interactions between Scenario and Experience were of primary interest, while main effects of Scenario were of secondary interest and more of a 'manipulation check' nature since the scenarios were included for variation in task complexity – which should yield strong effects on all three dependent variables (i.e., need of assistance, total time required, and risk of error).

4 Results

4.1 Occurrences during internship

In total 93 respondents started the survey, whereof 77 completed it. Thus, each situation has between 77 and 93 responses. Most (95%) were freight train drivers. For each of the 43 situations, the question was how many times this had occurred during the past year. The range was normally 0–100 and for some situations, less likely to occur, 0–40.

Average occurrence for each situation is displayed in Fig. 1. The answers were multiplied by 0.3 to match the driver average annual working hours, which is around three times the internship.

Please note that the maximum frequency is 16, however this is much lower than the theoretical maximum. For example, if a situation were to occur once a day for one year, the maximum would be about 84. For details on the 43 situations, "Appendix A". Henceforth the situations will be referred to by their numbers.

Most situations (54%) occur less frequently than once per internship period. Some are exclusively special cases, however a train driver is still expected to handle them correctly. For example, Driving a train without an automatic train protection system in an ATC-equipped area (35); Detector alarm concerning an overheated bearing (30); A level crossing signal that was off or indicated stop (24); Passage of a main signal indicating stop after movement authority with the addition "control the points" (Am. *turnouts*) given by the signaller (Am. *dispatcher*) (22). For System S, Blocked-line-operation lines (23), there were large variations with many respondents reporting no occurrence (84%), while the highest reported occurrence was 60 times.

Six of the 43 situations occur on average once or twice. Again, there were large variations in the following two situations with many respondents reporting no occurrence: A pre-planned blocked-line-operation that can be implemented and used at any open line (19) and A directly-planned blocked-line-operation that can be implemented and used at any open line (20), were non-occurrences were reported by 72% and 50% respectively. Among those 6 situations were also ATP-failure occurs during train movement (16) and Major balise transmission failure inside an operation zone (15).

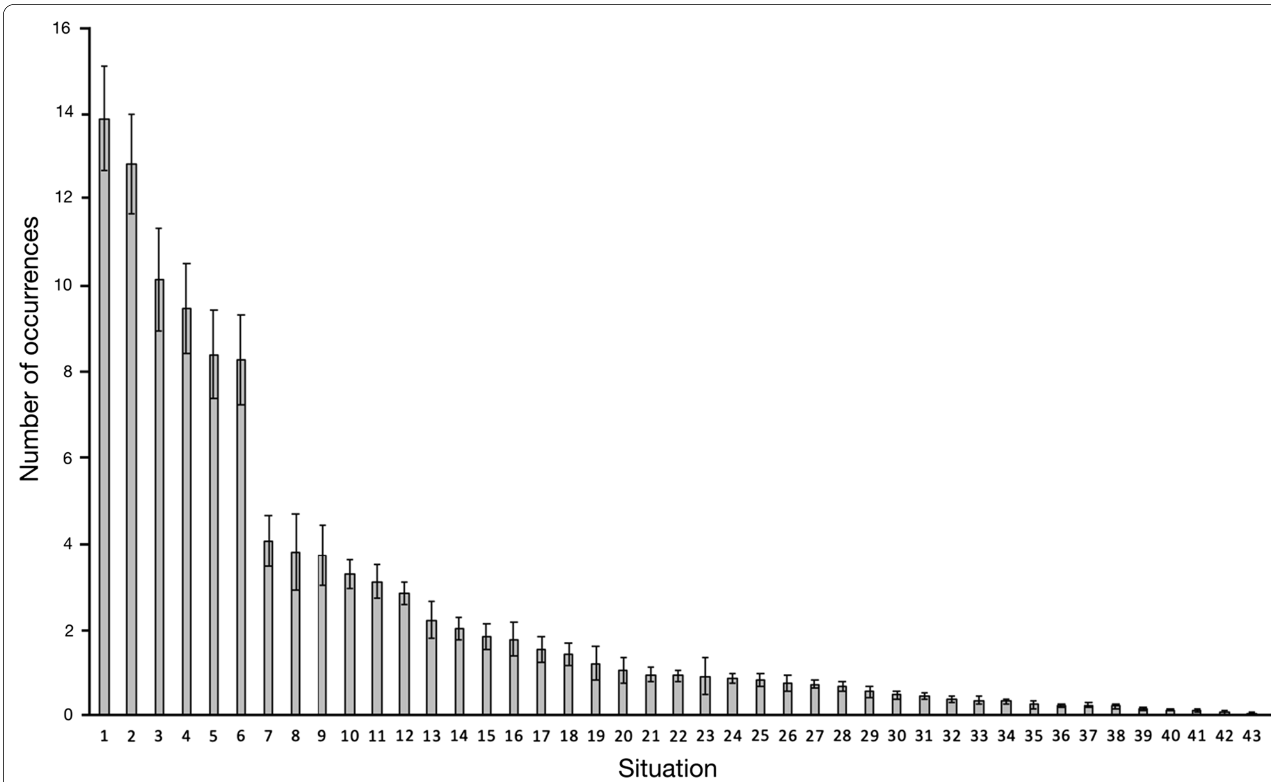

Fig. 1 Mean number of occurrences (± *SE*) per situation and internship period

Eight situations occur on average between two and five times. Notably, 58% of the respondents stated that they did not run on System M, Telephone block lines (8), during the last year, while a few reported 100 occurrences or more. Driving in very slippery conditions (7) as well as Driving with very limited visibility (10)] also occur between two and five times per internship period.

Finally, six situations occur between five and fourteen times. All these involve different forms of shunting movements or different tasks during shunting, for example To couple train vehicles as a driver or from the ground (1, 2).

4.2 Likelihood of incident or accident, and representativeness of situations

The response rate was 11 train drivers (61%), whereof 10 completed it. Representativeness was rated as high, with scores ranging between 4 and 6 (very likely), $M=4.8$. For the rated likelihood of the 43 situations leading to an incident or accident, the responses generally showed great variation. Most (39) of the situations had a range of 4 points or more, 10 situations had a range of 5 points, and 4 had a range of 6 points on the six-point scale. This suggests that instructors may interpret the scenarios differently, or that the instructors vary considerably regarding experiences, or a combination of both. There was no correlation between likelihood and that a situation would lead to incident.

4.3 Expectations on a novice train driver

For the questionnaire regarding expectations directed to train educators there were 30 respondents, 25 of whom completed the entire survey.

4.3.1 Amount of assistance needed

Figure 2 presents the expected assistance time needed for the experienced and novice train drivers, respectively, for each of the six scenarios. The scenarios, described in "Appendix B", are sorted by task complexity from low to high.

There was a main effect of Scenario, $F(5, 120)=10.94$, $MSE=178.20$, $p<0.001$, $\eta_p^2 = 0.31$. This shows that task complexity was successfully manipulated across the six scenarios, which can be seen in Fig. 2. The main effect of Experience was $F(1, 24)=70.82$, $MSE=39.58$, $p<0.001$, $\eta_p^2 = 0.75$. Thus, novice drivers are expected to require much more assistance than do the experienced drivers). The interaction effect of Scenario × Experience was $F(5, 120)=8.59$, $MSE=11.47$, $p<0.001$, $\eta_p^2 = 0.26$, which basically shows that the greater the task complexity, the greater the difference between experienced and novice drivers expressed in minutes.

4.3.2 Risk of error decisions

The risk of error decisions per scenario for experienced and novice drivers, respectively, as rated by the educators and employers is displayed in Fig. 3.

The effect of scenario yielded $F(5, 120)=2.56$, $MSE=106.17$, $p=0.03$, $\eta_p^2 = 0.10$; again validating the manipulation of task complexity such that the more

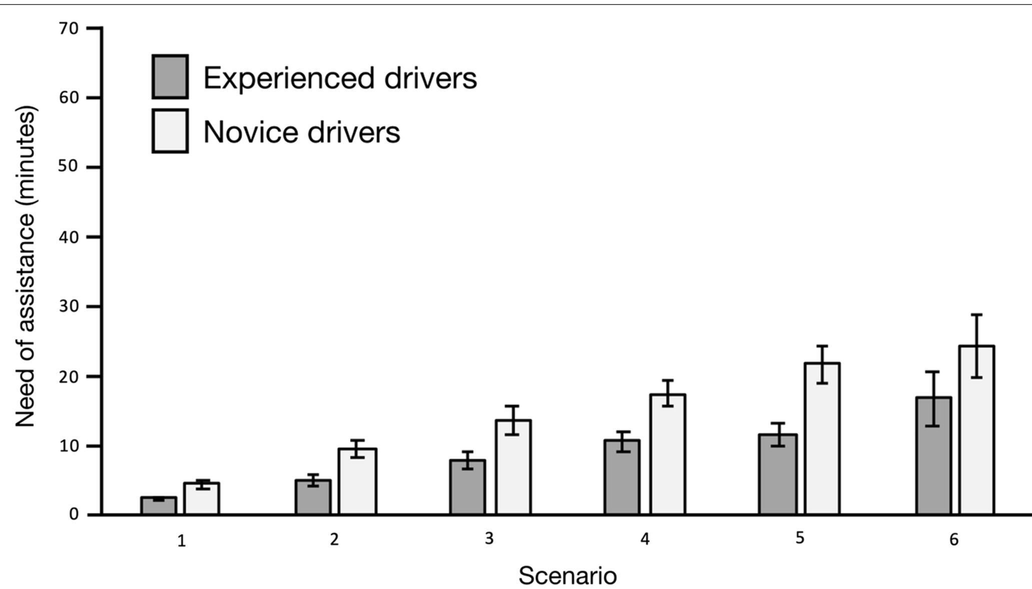

Fig. 2 Mean estimated time required for assistance (± *SE*) per scenario for experienced and novice drivers, respectively

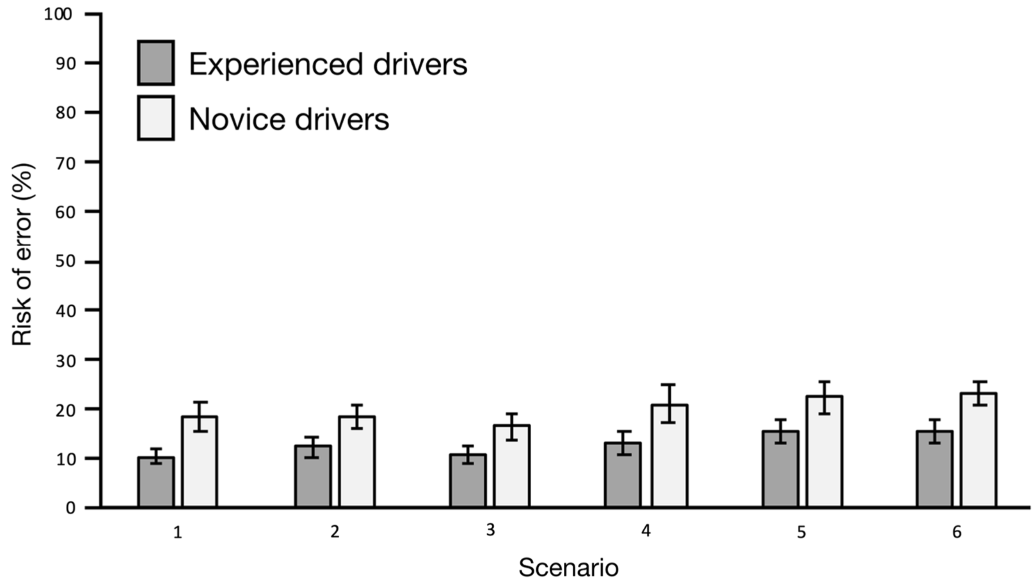

Fig. 3 Mean percentage of estimated risk of error decisions (± *SE*) per scenario for experienced and novice drivers, respectively

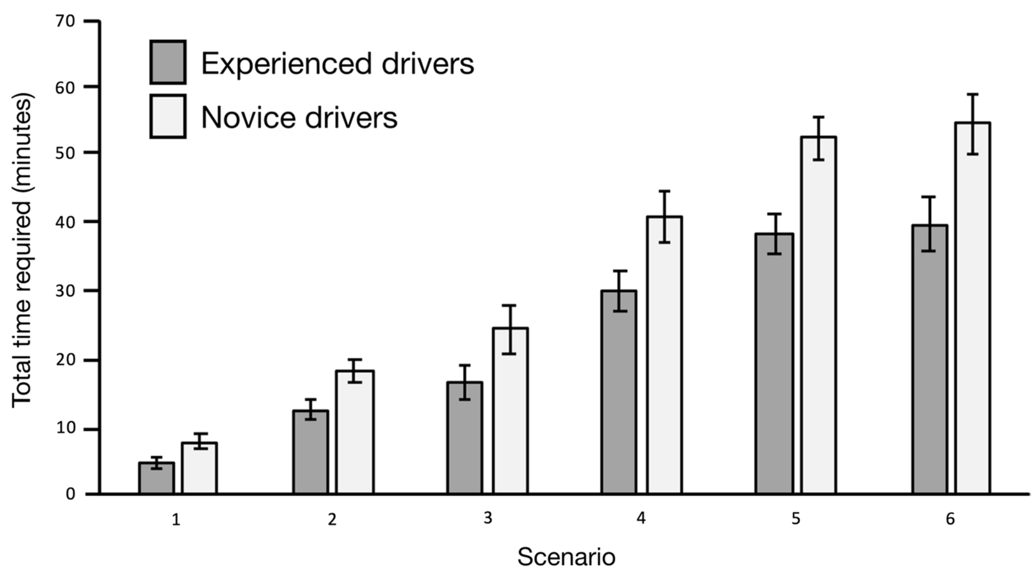

Fig. 4 Mean estimated total time required to complete each scenario (± *SE*) for experienced and novice drivers, respectively

complex the task, the greater the risk of error. Experience yielded $F(1,\ 24) = 28.49$, $MSE = 131.59$, $p < 0.001, \eta_p^2 = 0.54$, such that novice drivers are expected to be more prone to erroneous decisions than experienced drivers, see Fig. 3. There was no interaction effect.

4.3.3 Time efficiency

Figure 4 presents the total time required by experienced and novice drivers, respectively, to complete the whole scenario, as estimated by the educators and employers.

Again, the main effect of Scenario validated the manipulation of task complexity, $F(5,\ 120) = 49.05$, $MSE = 6608.21$, $p < 0.001$, $\eta_p^2 = 0.67$. Experience again yielded a main effect, $F(1,\ 24) = 129.47$, $MSE = 51.04$, $p < 0.001$, $\eta_p^2 = 0.84$, such that novice drivers are expected to require more time than their experienced colleagues.

There was also an interaction effect of Scenario × Experience $F(5, 120) = 21.80$, $MSE = 12.57$, $p < 0.001$, $\eta_p^2 = 0.48$, such that the more complex the task, the greater the difference between experienced and novice drivers to solve the task, expressed in minutes, see Fig. 4.

5 Discussion

5.1 Occurrences of pre-defined situations

Most situations occur less than once per internship period, which implies that lots of students do not even experience when the supervisor handles them. Regarding the handful of situations that occur on average once or twice, the students may only watch when the supervisor handles them, instead of practicing themselves. Situations with 2–5 occurrences are likely to be experienced by more students, however, the range is wide, and many respondents reported no occurrences. Out of 43 situations, only 6, which occurred 5–14 times, are likely to be experienced by most students.

The employer cannot rely on practical experience from any particular situation, except for train driving and shunting. The point is not that a certain situation occurs only 0.5 or 0.8 times per internship period, but to highlight the risk that many situations *will not* be experienced during the internship. In some rare situations, for example *Detector alarm concerning an overheated bearing* or *Experienced a level crossing signal that was off or indicated stop*, a mistake may lead to an incident or accident.

The train-driving students lack knowledge of familiarity and should hence be regarded as novices, according to Dreyfus [8]. Due to lack of practical experience, the novice needs more time to handle a new situation and is at higher risk for making a mistake.

5.2 Expectations on novice train drivers

Not surprisingly, the expectations on novice drivers are lower than on experienced drivers. With practical experience being the main aspect distinguishing the two driver categories, responder judgements can be assumed to be based mainly upon that fact. In that respect, the respondent's expectations on the drivers' need of assistance, risk for error decisions, and time efficiency are reasonable and in line with previous research and models [8, 12, 18, 21]. Further, the risk of a novice making a mistake, compared to an expert, was estimated to increase with the complexity of the situation. This is in accordance with the Dreyfus [8] model such that a more complex situation increases the gap between the novice and the expert.

The results strongly suggest that experienced as well as novice drivers prioritize safety over efficiency. Firstly, there was a considerably smaller effect of scenario on risk of error decisions than on time required to use assistance and on total time required to solve the task (i.e., complete the scenario). Secondly, there was an interaction effect between scenario and experience for both need of assistance, and for total time (see Figs. 2, 4, respectively), but not for risk of error (see Fig. 3).

As can be seen in Figs. 2, 3 and 4, the proportional difference between novice versus experienced drivers was generally constant and sizeable across all three dependent measures (i.e., need of assistance, risk of error, and total time) and all six scenarios. That is, the novice drivers were generally estimated to require about one third more time, and to have about one third greater risk of making errors.

5.3 Practical implications and suggestions for future work

The present study shows that many special cases are rarely encountered in real-life train driving, which means that it is unlikely that the novice encounters all of them during the internship. The scores for the 43 situations and the 6 scenarios, as well as the method of inquiry, can be used for developing the train driver education.

As the novices already possess the theoretical knowledge, mainly practical training is required to become a safer and more efficient driver. Because of a congested Swedish railway and the difficulty of controlling the reality as a training environment, another method to complement the internship is necessary. Train simulators have been shown useful for training energy-efficient driving with regenerative power supply [1] and for practicing new signal systems, such as the European Rail Traffic Management System (ERTMS) [2].

Based on the results of this study, simulator training should focus on two aspects. Firstly, simulator training can be used as a complement to the internship, to ascertain sufficient practice of less frequent special cases. Secondly, the safe simulator environment is useful to practice combinations of situations, as well as various external circumstances (i.e., weather, track, or type of train). In reality, a situation is rarely isolated, but unfortunate combinations of circumstances may increase both difficulty and the risk of an accident. The suggested simulator-based training makes more situations familiar, which effects both time efficiency and safety. Practicing different combinations of situations in various contexts also increases the possibility that the driver can handle a new situation as well as a situation in an entirely novel context, corresponding to the third step in the Dreyfus five-stage model, competent.

To achieve the greatest training effect, it is important to create a realistic simulator environment [17, 25]. According to Tichon [29] not only should the special cases be realistic, but also the distractions used for making the scenario more complex. A user-center development of train-driver simulators with real Swedish tracks has been conducted for some years involving Swedish train operators and educators [28], which would be useful for the suggested simulator training. More empirical data about how effective simulator training for train drivers should be designed is necessary. The outcome of an effective pedagogical simulator training regime would be a more economical (i.e., a more efficient) and safer (i.e., with fewer accidents) railway.

5.4 Limitations

Some limitations of the present study are worth mentioning. First, although the railway worldwide has many similarities, it is also in many ways nationally bounded. For example, the regulations, rules, and train protection systems differ between countries and regions. This makes it difficult to generalize the results from Sweden to other countries. Secondly, due to difficulties in obtaining relevant statistics from a Swedish privatized railway, our starting point in producing the questionnaires was the expertise of the industry rather than the actual statistics about incidents and accidents. Thirdly, there may be other important factors other than experience that contribute to the fact that novices are expected to perform at a lower level than experts. For example, stress or overconfidence may be such factors, and exactly which factors and how they contribute to the performance would be interesting to study closer.

6 Conclusions

The combined results show that many situations that require correct and efficient handling by the driver can with the present curriculum for train-driver education not be expected to be trained, which is also reflected in the expectations on the novice drivers. The lower expectations on the novice drivers are presumably realistic and may to some extent be helpful—if colleagues and dispatchers allow for it. Novice drivers, as well as experienced drivers, are also expected to prioritize safety over efficiency which may be seen as a gratifying result for Swedish train driving educators. However, correct and efficient handling by train drivers is crucial for safety both with regard to lives and infrastructure, time efficiency and economy. Even a small difference in expertise may make a large difference in terms of increased risk. It may therefore be argued that the practical training should ensure that most of the potentially critical situations that may occur should be practically trained until the students master them. Simulator training can be used as a complement to internship to ensure that the train drivers can master also various situations and special cases that rarely occur in real life.

Appendix A

Translation from Swedish to English

Translating Swedish railway operations into English is not easy. First, since Sweden belongs to the central European sphere of railway, the philosophy of how the railway works is different compared to North America or Great Britain. For example, in Sweden the track is divided into operation zones and open lines. In the former, train can pass and the dispatcher can control the signals and turnouts more detailed than in the open lines. The wordings used in this paper are British, which in some cases can be different from the words used in North America. Also, because of the different philosophies, the expressions may sometimes have a slightly different meaning in different countries.

The 43 situations, translated from Swedish, sorted by occurrence (see Fig. 1)

1. Having coupled vehicles placed on the ground during shunting
2. Been a driver during shunting with someone else coupling vehicles placed on the ground
3. Been a driver during shunting in a non-signal-controlled area (siding)
4. Been a driver during shunting in cooperation with a shunter giving signals by hand or radio
5. Been a driver during shunting on a signal-controlled area when the signaller has released the control of the area to the driver
6. Given signals by hand or radio to a driver during shunting
7. Driven a train on very slippery rails.
8. Been a driver at telephone blocked lines (with locally controlled operation zones)
9. Driven a train when a minor balise transmission failure occurs
10. Driven a train with a very limited view (e.g. heavy snowfall, fog or hard rain)
11. Driven a train when a major transmission balise failure occurs at the open line
12. Received a permission to pass a red signal given by the signaller on a special form with the addition “the points are in control”.

13. Been a driver when, without any information about the fault in advance, a main signal is green but the associated balise gives the information stop.
14. Needed to troubleshoot your traction unit in order to continue driving
15. Driven a train when a major balise transmission failure occurs inside an operation zone
16. Been a driver when an ATP-failure (with ATC) occurs during train movement
17. Received information from the signaller on a special form regarding temporary speed reduction without signalling from balises or signs
18. Been contacted by the signaller regarding detector alarm concerning wheel damage in your train
19. Been a driver or responsible of a pre-planned blocked-line operation
20. Been a driver or responsible of a directly planned blocked-line operation
21. Carried out a failed brake test resulting in having to disengage a brake
22. Received a permission from the signaller on a special form to pass a red signal with the addition "control the points"
23. Been a driver at blocked line operation lines (lines that can only be operated by blocked line operation)
24. Been a driver when a level-cross signal or a level crossing distant signal where off or indicated stop before reaching the level crossing.
25. Received a permission by the signaller to pass a shunting dwarf signal indicating stop during shunting.
26. Being a driver when given the information from the signaller in advance, a main signal is green but the associated balise gives the information stop.
27. Received information from the signaller on a special form regarding an incorrect level-crossing in your route
28. Had to turn off a brake due to another reason than after a special air-brake test intended to recognize which brake or brakes leaks air.
29. Been contacted by the signaller regarding detector alarm concerning overheated wheel in your train
30. Been contacted by the signaller regarding detector alarm concerning overheated bearing in your train
31. Been a driver when the overhead line turns powerless during train movement and the power do not return shortly
32. Been a driver when a person guards an incorrect level-crossing
33. Been a driver when an ATP-failure (with ETCS) occurs during train movement
34. Driving backwards during train movement inside an operation zone
35. Driving a train without automatic train protection (ATP) in an ATP-equipped area
36. Been a driver or responsible for a directly planned blocked-line operation intended to help another train in need of assistance.
37. Had to uncouple vehicles from your train during train movement before reaching the trains final destination
38. Been a driver when a signal suddenly turned to stop which led to a signal passed at red
39. Been in need of asking the signaller for an assisting train as a consequence of a train failure
40. Driving backwards during train movement on the open line
41. Been in need of a special air-brake test intended to recognize which brake or brakes leaks air.
42. Been a driver or responsible for a blocked-line operation or shunting inside an area allowed for work. No train movements are allowed inside the area.
43. Received a permission by the signaller on a special form to pass a red signal with the addition "control the points". The next turnout had a moveable point crossing.

Appendix B

Translation from Swedish to English

The purpose of this translation is to give English-language readers an opportunity to understand the content of the questionnaire.

The six scenarios, translated from Swedish, sorted by occurrence (see Figs. 2, 3, 4)

Scenario 1 The train driver experience a major balise transmission failure (MBTF) inside an operation zone. The speed was 120 kph when the MBTF occurred and it was not known by the driver in advance. The driver cannot see the next main signal until after 500 m after the MBTF. The next as well as the second next main signal is green. The rulebook implies that the driver has to decrease the speed to a maximum of 40 kph and to rely on his or her vision since MBTF causes the information from the ATP to disappear. The information comes back when passing a balise just beyond the second main signal. Estimate how you expect the driver to handle the whole process until the information comes back to the ATP.

Scenario 2 The train driver is at a main signal inside an operation zone, when called by the signaller. On a special form, the driver gets a permission to pass a red signal, with the condition "control the points". On the way to the next main signal there are two points of which one is clearly pointing towards the wrong direction and needs to be changed manually by the driver. Estimate how you expect the driver to handle the whole process from the phone call until reaching the next main signal.

Scenario 3 The 400 m long train is on the open line about 6 km from the next operation zone when an ATP-failure occurs. The speed-limit on the line is 100 kph. Estimate how you expect the driver to handle the whole process until he or she reaches the next operation zone and receives a permission from the operative work management to continue without a working automatic train protection (ATP).

Scenario 4 About 3 km from the next operation zone, the driver is called by the signaller regarding a detector alarm concerning overheated bearing detected on axle 14 on the train. The rulebook implies that the driver now must run to the next operation zone with significantly reduced speed. On the next operation zone the driver needs to ask the signaller for special protective measures for the adjacent track when inspecting the train. Estimate how you expect the driver to handle the whole process from the initial phone call until necessary controls on the train are performed.

Scenario 5 The 400-m long train is in front of a main signal inside an operation zone with three tracks. One wagon in the middle of the train must be uncoupled and left on one of the tracks. The signaller gives the driver a permission for shunting with released control of the points at the whole operation zone. To complete the shunting, the driver also must pass the border between the operation zone and the open line for which another permission from the signaller is necessary. Estimate how you expect the driver to handle the whole process from the initial call until the shunting is complete.

Scenario 6 The train driver is inside an operation zone while called by the signaller. Since another train is blocking the way, the signaller wants to lead the train another way by directly plan a blocked-line operation from this operation zone to the next (a distance of 20 km). This means the driver and the signaller must fill in a special form before the driver runs with a speed limit to 70 kph over the open line until arriving into the next operation zone. Estimate how you expect the driver to handle the whole process until he or she arrives to the second operation zone.

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Authors' contributions
All authors read and approved the final manuscript.

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Availability of data and materials
The datasets generated and/or analysed during the current study are not publicly available due to confidentiality reasons but are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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