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VISUAL SEARCH WHILE AMBULANCE DRIVING: EFFECTS OF DRIVING CONTEXTS

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ABSTRACT

This study aims to document the visual search of experienced ambulance drivers in different simulated driving task scenarios. The cohort consisted of 16 experienced paramedics (4 women and 12 men, aged 38 ± 8.3 years, 16 ± 9 years of experience). Each participant completed fifteen minutes of simulation driving tasks. Ten visual regions of interest and 12 driving situations, divided into three driving contexts (one non-urgent and two urgent), were selected. The findings suggested that the ambulance drivers' strategies were adaptive, assisting them in detecting potential hazards. It was observed that when the driving demands increase, experienced ambulance drivers had longer fixation times, more frequent scanning, and a greater variety of search patterns. The study also suggests that experienced ambulance drivers may employ similar visual search strategies to those used by other experienced drivers, as the literature shows. Tailored interventions should be developed to enhance this important skill.

Ambulance drivers are part of a group that can be defined as emergency vehicle drivers and are exposed to high risks of collisions due to secondary tasks such as speeding, necessary conversing, monitoring messages, violating normal driving rules under certain circumstances, and activating emergency equipment (Hsiao et al., 2018; Kun et al., 2015). An ambulance driver refers to the person who operates an ambulance, and this role is not limited to paramedics (e.g. EMT, firefighters). Ambulance drivers are also exposed to a higher risk of work-related collisions and road fatalities than the general population (Maguire et al., 2002) and other commercial or similarly sized vehicles (Delavary et al., 2023). For the past twenty years, several studies reviewed collisions involving ambulance vehicles (Custalow & Gravitz, 2004; Delavary et al., 2023; Delavaryforoutaghe & Lavallière, 2022; Maguire et al., 2002; Ray & Kupas, 2007; Sanddal et al., 2010; Watanabe et al., 2019). Unfortunately, there has been little progress in enhancing ambulance driving safety. Human factors continue to be the primary cause of ambulance collisions (e.g.

inadequate urgent driving training, lack of urgent driving experience, driver distraction) (Delavary et al., 2023). For many years, one important cause identified in the literature was the drivers' strategies of visual search (Chapman & Underwood, 1998; Crundall & Underwood, 1998; Mourant & Rockwell, 1972; Recarte & Nunes, 2003; Strayer & Johnston, 2001). It was documented that novice drivers, as well as high perception of hazards or high traffic density, and high level of cognitive workload or distraction, can lead to a reduction of visual scanning and a quicker fixation time (Chapman & Underwood, 1998; Crundall et al., 2003; Crundall & Underwood, 1998). Consequently, drivers cannot accurately detect or decode road information (e.g., interactions with other road users, road conditions, road signs) to adequately estimate collision risk (Mourant & Rockwell, 1972; Underwood, 2007). To our knowledge, no recent data is available on ambulance drivers' visual search patterns. Documenting these visual behaviors could be useful for improving ambulance driving safety through proper training interventions.

The aim of this study was to document the visual search of experienced ambulance drivers in different simulated driving task scenarios. More specifically, the visual search of the current study reported the average fixation time per region of interest (ROI) per driving situation, the average number of ROI changes per driving situation, the percentage of time spent per ROI in each situation, and the frequency of occurrence between each ROI per driving situation. It was expected that visual search would be more diverse and that horizontal scanning would be more important when approaching intersections or in areas with high traffic density compared to straight-line driving (Crundall & Underwood, 1998). It was also expected that changes would be observed when dispatchers called or when patients were being transported. Similarly to a study conducted by Crundall et al. (Crundall et al., 2003), where results showed an increase in fixation times in emergency and pursuit situations, it was expected that fixation times would be shorter and horizontal scanning would increase when patients were being transported.

METHODOLOGY

Study Design

This study employed a quasi-experimental design to evaluate visual search while experienced ambulance drivers drove an ambulance simulator through three simulated driving tasks: a non-urgent driving task and two urgent driving tasks (pre- and post-patient care intervention).

Participants

Recruitment emails were sent throughout the province of New Brunswick (Canada) with the cooperation of the Ambulance New Brunswick organization. Twenty-five paramedics volunteered for this project (n = 25). All experienced ambulance drivers recruited were paramedics. Among these paramedics, three left at the beginning of the data collection, three left after familiarization with the ambulance simulator due to simulation sickness and three were removed from the analysis due to equipment failure, resulting in data loss. Thus, a total of sixteen paramedics were considered in this study (n = 16). The cohort consisted of 4 women and 12 men, aged 38 ± 8.3 years (M ± SD), with 16 ± 9.0 years of paramedic experience. All paramedics took the day off before participating in the study to ensure they had a whole night's sleep.

Procedures

The assessment was conducted at the university's driving laboratory. Upon arrival, each participant was briefed on the data collection process, read an information letter, and signed a consent form approved by the university's research ethics board to participate in this study (approval number 1213-059). Afterward, all participants completed a demographic survey (sex, age, and years of experience). Before data collection began, participants were familiarized with the ambulance simulator through a 10-minute driving session, which allowed them to adapt to the simulated driving environment and controls. At this point, three participants prone to simulator sickness were excluded from the study (Mackrous et al., 2014).

Simulated Driving Tasks

The simulation driving tasks battery was developed in partnership with a paramedic instructor from New Brunswick ambulance services to ensure that the tasks were stressful and challenging. All participants underwent the same driving simulation. The simulation was divided into three sections. The first section was composed of 5 minutes of non-urgent driving (on a highway) followed by a second section consisting of 5 minutes of urgent driving to the location of a fictitious patient. Finally, the third section consisted of 5 minutes of urgent driving from the patient's location to the hospital. Simulated driving scenarios took place on clear days with full daylight and long-range visibility. The non-urgent driving occurred mostly on a highway with low traffic density (without potential risks of collisions). In contrast, both urgent driving scenarios were set in city environments with varying levels of traffic density, leading to an increased number of potentially conflicting situations with other road users. None of these scenarios required evasive maneuvers (e.g. hard braking, significant steering adjustments). Participants were guided through the driving simulations by a pre-recorded dispatcher's voice, which provided information along the route, whether heading to the scene or the hospital. Additionally, the dispatcher's voice delivered updates on the status of a fictitious patient. Since the call involved an unstable cardiac patient, urgent driving to the hospital (post-care) was accompanied by the added distraction and stress of a loud, irregular heartbeat noise from a cardiac monitor attached to a manikin. This protocol was fully detailed in a previous study (Tremblay et al., 2020;)

Apparatus

The driving simulations were conducted using a driving simulator (VS600M, Virage Simulation, Canada) with a virtual ambulance taking the form of a cube truck ambulance. The ambulance simulator consisted of a driver's seat, steering column, pedals, automatic transmission and a dashboard, all of which were mounted on a hydraulic three-axis motion/vibration platform that provides force feedback and vibration. Three 52′ LCD displays provided a 180 front view with a 1920 X 1080-pixel resolution per display. Rear-view and side-view mirrors were simulated through these screens. It should be noted that the ambulance vehicle used in the simulation did not have a central rear-view mirror. One touchscreen (Elo Touchsystems 2700 Intellitouch USB) located to the driver's right provided additional control for the ambulance sirens. Two synchronized webcams (QuickCam Pro for notebook, Logitech, Switzerland) were installed on the driving simulator to record the 180 front view ('what the participant was seeing') and the participant's face (head, eye positions). The resolution and frequency of these video recordings were 640 X 360 pixels and 30 frames per second.

Visual Search while Driving

By analyzing the participants' head and eye positioning from the face video, it was possible to determine which regions of interest (ROI) they were focused on while watching and driving throughout the simulation (Lavallière et al., 2012). Ten ROIs were identified in the ambulance simulator. Nine ROIs were located within the driving environment of the participants (Figure 1), and one was identified as an 'indeterminate area' (IND), which was used when information was unavailable or impossible to extract.

The visual search analysis was done a posteriori. Throughout the driving scenario, 12 situations were selected and analyzed frame by frame to identify the start and end of each scenario, considering a specific distance for standardized evaluation between evaluations. Table 1 presents the 12 driving situations divided into three driving contexts (one non-urgent, two urgent ('en route', 'to the hospital')).

ANALYSIS

To report the visual search among experienced ambulance drivers in different driving situations, the current study compares:

- The average fixation time per ROI per driving situation.
- The average number of ROI changes per driving situation.
- The percentage of time spent per ROI in each situation.
- The frequency of occurrence of links between each ROI per driving situation.

Prior to conducting the inferential tests, a visual inspection of the frequency distribution histogram was performed, followed by the Shapiro-Wilk and Levene tests to evaluate normality and homogeneity of variance, respectively. This preliminary step confirmed the use of non-parametric tests throughout the analysis. Results were significant when

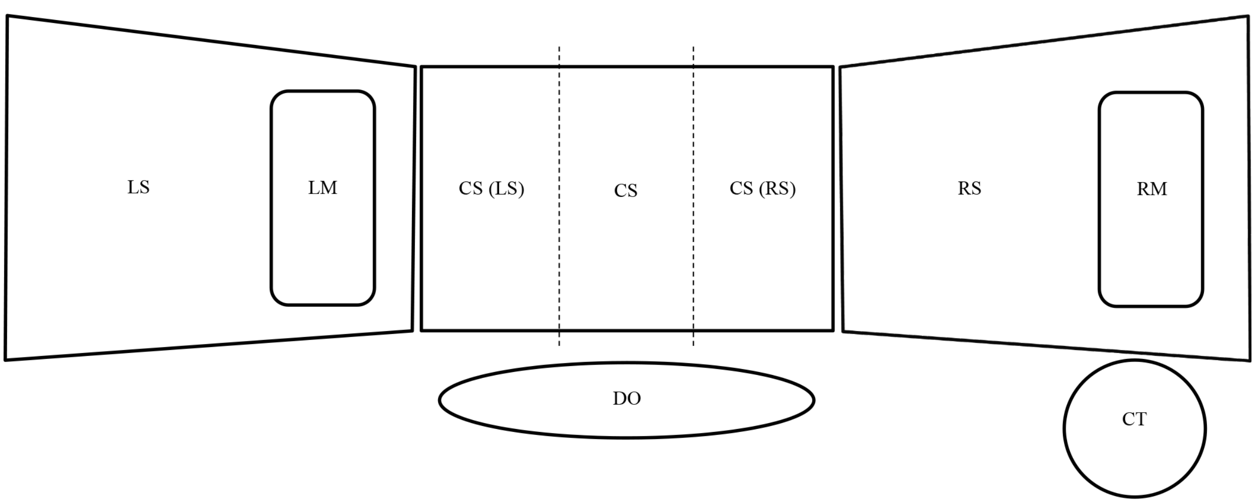

Figure 1. Scheme of the driving environment of the driving simulator divided into 9 regions of interest (ROI).

Note: LS: left screen, LM: left mirror, CS (RS): right section of central screen, CS: central screen, CS (LS): left section of central screen, RS: right screen, RM: right mirror, DO: area with the dashboard and the odometer, CT: command terminal (light and siren control).

the p was less than 0.05. Since Kruskal-Wallis tests could not be used due to missing data in some participants, this study proceeded with paired-wise Wilcoxon tests. Thus, Wilcoxon tests were performed on the first two objectives and chi-squared tests were performed on the third objective. More specifically, nine comparisons of interest were computed among the driving situations to compare similar situations as defined in Table 1:

- Straight line: 1 vs. 2, 1 vs. 8, 2 vs. 3, 2 vs. 8, 3 vs. 8.
- Pedestrian crossing: 4 vs. 12.
- Left and right turns: 5 vs. 10, 6 vs. 11.
- Red light: 7 vs. 9.

Driving situations		Context		
		Non-Urgent	Urgent	
#	Descriptions		'en route'	'to hospital'
1	Straight line without traffic	X		
2	Straight line without traffic		X	
3	Straight line with traffic		X	
4	Pedestrian crossing		X	
5	Left turn at an intersection		X	
6	Right turn at an intersection		X	
7	Red light at an intersection		X	
8	Straight line without traffic			X
9	Red light at an intersection			X
10	Left turn at an intersection			X
11	Right turn at an intersection			X
12	Pedestrian crossing			X

Table 1. Driving situations organized by context.

For the fourth objective, similarly to Olsen et al. (Olsen et al., 2005), a calculation of the occurrence frequency of the link between ROI was carried out for driving situations that were significantly different in the number of ROI changes. Missing data were due to malfunctions with video or simulator equipment; thus, some participants' video segments could not be used. The number of missing data per participant and per driving situation is provided in Appendices A1 and A2. Data were processed and computed with MS Excel version 16 and SPSS version 26.0.

RESULTS

Average Fixation Time per ROI per Driving Situation and Average Number of ROI Changes per Driving Situation

The duration of gaze on the ROI varies according to the driving situation and the driving context (see Table 2 and Appendix A for more details). There were several differences in straight-line driving situations (refer to Table 1 for a detailed description). In fact, there were three ROIs with notable differences between the straight line without traffic before (non-urgent) versus after dispatcher call ('en route') (LM, CS (LS) and DO). Also, four ROIs had notable differences between the straight line without traffic non-urgent context and the straight line without traffic 'to hospital' context (LM, CS(LS), DO and CT). Some differences were observed in gaze towards the central screen and the left side of the central screen between the two driving situations when approaching a crosswalk (CS (LS) and CS). The ROI with the most differences between driving situations were the left section of the central display. Three significant differences appear with a median fixation time value of 0.00 because the difference between them is in their third quartile (see Appendix A for more details). Table 3 shows that the average number of ROI changes per driving situation was significantly different only between the two left-turn situations and the two right-turn situations (see Appendix B for more details).

ROI	Straight Line					Pedestrian	Turns		Red Light
	1 vs 2	**1 vs 8**	**2 vs 3**	*2 vs 8*	*3 vs 8*	*4 vs 12*	*5 vs 10*	*6 vs 11*	*7 vs 9*
LS	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.31*	*0.00*	*0.00*
LM	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
CS (LS)	0.00	0.18	0.00	0.175	*0.18*	*0.43*	*0.04*	*0.41*	*-0.28*
CS	0.18	-0.66	-0.99	-0.84	*0.16*	*0.59*	*-0.33*	*-0.13*	*0.04*
CS (RS)	0.00	0.17	0.08	0.17	*0.08*	*-0.16*	*-0.05*	*0.02*	*0.09*
RS	0.00	0.00	0.00	0.00	*0.00*	*-0.23*	*-0.27*	*-0.99*	*0.11*
RM	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*
DO	-0.48	-0.47	0.00	0.017	*0.02*	*0.00*	*0.00*	*0.00*	*0.00*
CT	0.00	0.24	0.00	0.24	*0.24*	*0.00*	*0.00*	*0.00*	*0.00*
IND	0.00	0.00	0.00	0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*

Table 2. Median fixation time differences (in seconds) between driving situations related to ten regions of interest (ROI).

Note: Values are presented in the difference of median (in seconds). Grey shade values indicate significant differences ($p < 0.050$). CS: central screen, CS(LS): left section of central screen, CS(RS): right section of central screen, CT: command terminal (light and siren control), DO: area with the dashboard and the odometer, IND: indeterminate, LM: left mirror, LS: left screen, RM: right mirror, RS: right screen

Straight Line					Pedestrian	Turns		Red Light
1 vs 2	**1 vs 8**	**2 vs 3**	*2 vs 8*	*3 vs 8*	*4 vs 12*	*5 vs 10*	*6 vs 11*	*7 vs 9*
0	2	0	2	*0*	*1*	*12*	*4.5*	*3.5*

Table 3. Comparison of the average number of regions of interest (ROIs) that change per driving situation

Percentage of Time Spent per ROI per Driving Situation

The proportion of time allocated to each ROI varied according to the driving situation (Figure 2). Significant differences in these proportions were obtained in three comparisons:

1. The difference between the two pedestrian crossing driving situation:. The main differences were between the central screen and the left section of the central screen, which was viewed more in the 'to hospital' context and the right section of the central screen and the right screen, which was viewed more in 'en route' context.
2. The difference between straight-line driving situations without traffic in non-urgent context and straight-line driving situations without traffic in 'to hospital' context: The main differences were between the dashboard mainly observed in straight-line driving without traffic in non-urgent context and the right section of the central screen and the command terminal more observed in the driving section without traffic in 'to hospital' context.
3. The difference between straight-line driving situations with traffic in 'en route' context and straight-line driving situations without traffic in 'en route' context: Most of the differences were between the central screen and the dashboard, which were viewed more in straight-line driving without traffic, and the right section of the central screen, which was viewed more in straight-line driving with traffic.

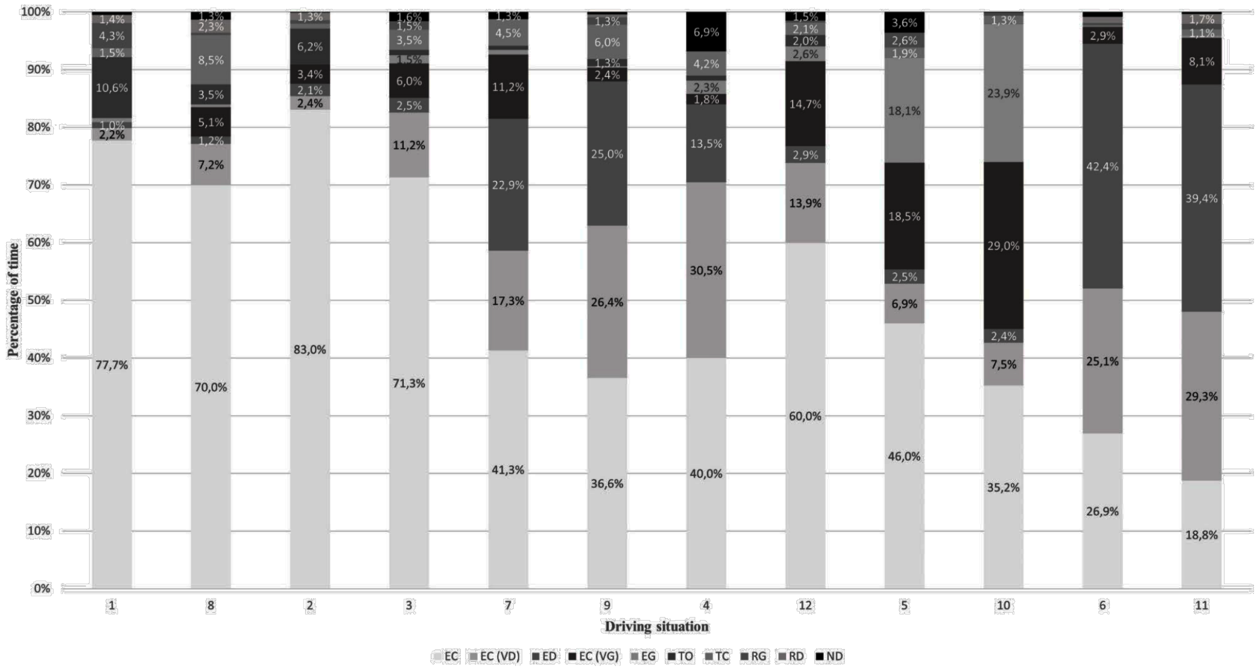

Figure 2. Percentage of time spent by ROI per driving situation.

Note: CS: central screen, CS(LS): left section of central screen, CS(RS): right section of central screen, CT: command terminal (light and siren control), DO: area with the dashboard and the odometer, IND: indeterminate, LM: left mirror, LS: left screen, RM: right mirror, RS: right screen. Values below 1% are not displayed on the figure.

Frequency of Occurrence of Links Between ROI per Driving Situation

Some links between ROI were specific to certain driving situations (see Figure 3). For example, return trips between the central and right screens were observed in both driving situations after patient recovery ('to hospital'), but not in both situations before patient recovery ('en route'). Certain links were also stronger in some contexts than in others. When comparing both left turns driving situations, we observed a link transfer when switching from driving 'en route' to driving 'to hospital' (such as the existing links between the central screen and the right screen) to new links such as the right screen to the left screen or the left screen to the dashboard. Additionally, when comparing two driving situations during a right-hand turn, it was noticed that some links present in 'en route' context disappear in favor of new links in 'to hospital' context. In both cases, the number of links increased between driving situations (three more between left turns and seven more between right turns). It is worth noting that the most significant number of links were found on the side where the driver was about to turn.

DISCUSSION

The aim of this research was to document experienced ambulance drivers' visual search in different driving situations on an ambulance simulator, and to study whether there was a difference in visual search according to work contexts (non-urgent vs. urgent). The results show that differences do exist between driving situations and that the contexts also influence visual search parameters. Overall, 13 significant differences were identified in average fixation time per region of interest across various driving situations. Nine of these differences concern straight-line driving situations. In these, fixation times

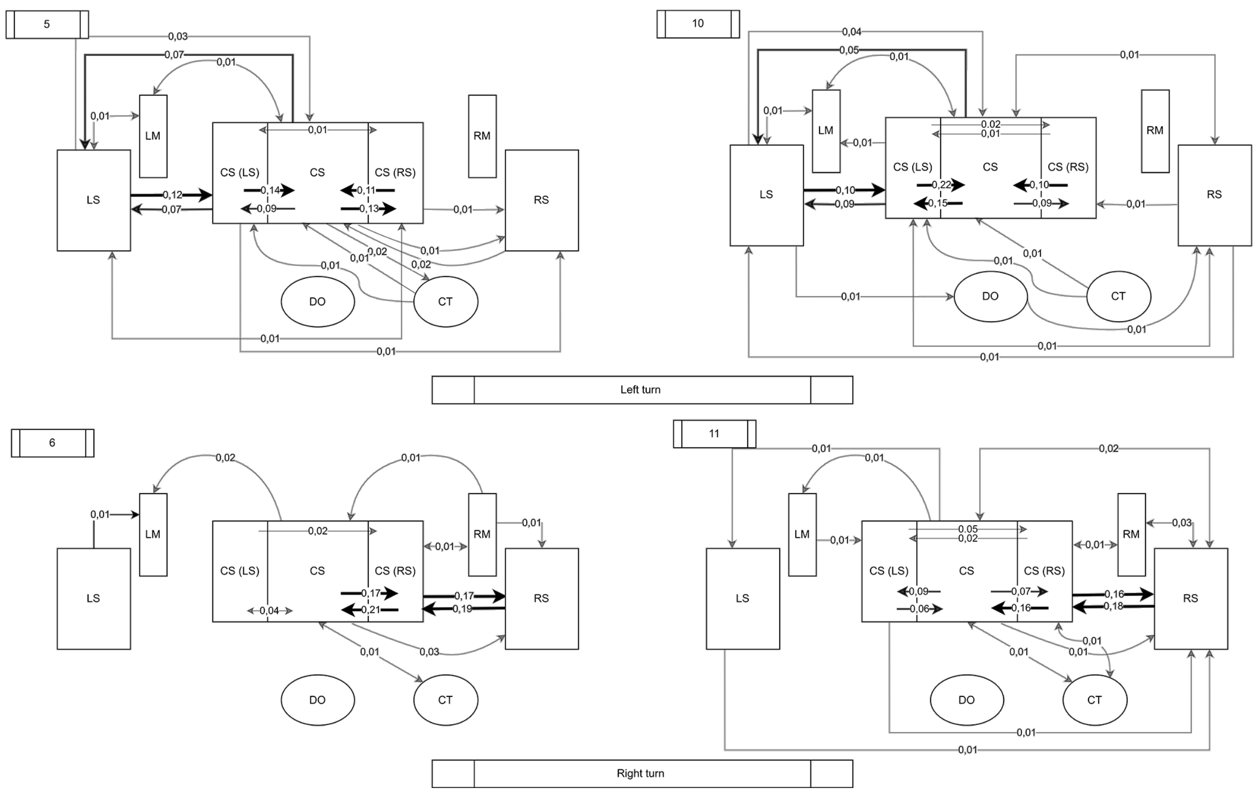

Figure 3. Frequency of linkage between ROIs as a function of driving situation.

Note. LS: left screen, LM: left mirror, CS(RS): right section of central screen, CS: central screen, CS(LS): left section of central screen, RS: right screen, RM: right mirror, DO: area with the dashboard and the odometer, CT: command terminal (light and siren control), IND: indeterminate (the link with indeterminate area doesn't appear).

decreased when the ambulance driver received the dispatcher's call ('en route') compared with before the call was received (two longer fixation times in the non-emergency situation compared to one longer fixation time in the 'en route' situation.), then increased when the ambulance drivers crossed a densely trafficked area (a longer fixation time in the presence of traffic) and remained higher when the patient had been recovered (a longer fixation time when driving 'to hospital'). Fixation times were similar for the 'en route' straight-line driving situation with traffic and the 'to hospital' straight-line driving situation without traffic. Of the five significant differences found in fixation time between situations in 'en route' and 'to hospital' contexts, three showed longer fixation times in 'to hospital' contexts. These results align with those of Crundall et al. (Crundall et al., 2003) and support our hypothesis, indicating that in emergency situations, all drivers presented longer fixation times compared to control situations (non-urgent) in an ambulance simulator. Horizontal scanning increased in 'to hospital' left- and right-turn situations compared with 'en route' situations. Indeed, an increase in the number of links and the creation of new links between ROI were also measured in these situations (Figure 3). These results also highlight that even in an urgent mode of driving.

In straight-line situations, the left-hand mirror and the dashboard/odometer were looked at the longest, in proportion of time (Figure 2), in the situation before the dispatcher is called. The right-hand mirrors and the control panel were most frequently used in the 'to hospital' context. Furthermore, the central screen was viewed at the highest percentage in the 'en route' situation without traffic, while the right and left screens and the right and left sections of the central screen were viewed more when traffic was present. This indicates that when traffic is present, the time spent in peripheral areas increases, suggesting a search strategy with more scanning in these zones but a longer fixation time (Table 2) to detect potential hazards, as expected and demonstrated by Robinson et al. (Robinson et al., 1972). Regardless of the straight-line driving situation, the central screen zones (EC, EC (VG), and EC (VD)) remained the most viewed zones, although the percentage of time allocated to them varied.

Olsen et al. (Olsen et al., 2005) showed that in a straight-line on-road driving situation (highway context), participants mainly viewed straight ahead (85.9% of the time) and spent the remaining time scanning the area containing the odometer and dashboard (4% of the time). In comparison to this study, while the time spent viewing straight ahead (84.8% of the time) was relatively similar, the time spent scanning the odometer and dashboard in the pre-dispatcher driving situation was higher (14.9% of the time). This time difference may be explained by the fact that the ambulance drivers spent less time looking at the central screen and perhaps they had a poorer appreciation of their speed on the simulator, despite the pre-simulation adaptation period. Also, in the study by Olsen et al., the left rear-view mirror and the left window were slightly looked at, with 2.1% and 1.5% of the time spent looking at them, respectively, whereas these areas represented 7% and 1.4% of the time among ambulance drivers, respectively. The right-hand mirror and right-hand screen were scanned 2.7% and 1.9% of the time for ambulance drivers, respectively, compared with 0.24% and 0.06% of the time for the Olsen et al. (2005) study sample, respectively. Finally, this Olsen et al., showed that participants spent 4.7% of their time looking at their rear-view mirror. Compared to the current study, it can be hypothesized that the distribution of attention is different for ambulance drivers. Since they do not have a rear-view mirror, the drivers must rely on their side mirrors to stay aware of the situation behind them. This situation becomes even more complex considering the blind spots that exist in comparison to a standard-sized vehicle.

The differences in the number of ROI changes between left-turn and right-turn driving situations were significant ($p = 0.007$ and $p = 0.025$, respectively). For left-turn situations, the number of ROI changes is higher in the 'en route' context. However, the number of links between ROI is higher in the 'to hospital' driving situation (Figure 3). This rise may indicate an increase in the diversity of visual search patterns, despite the time spent on each ROI not being significantly different (Figure 2). In the case of right-turn situations, the number of changes is higher in the 'to hospital' context. In addition, after patient recovery, ambulance drivers make new links between ROI (Figure 3). In the case of left-turn situations, the links between the central screen and the control panel and between the central screen and the right-hand mirror disappear once the patient has recovered ('to hospital') (Figure 3). During left turns, ambulance drivers of the current study showed a higher percentage of time looking at the left and right sections of the screens than drivers aged 25 to 55 with at least 10 years of driving experience (Romoser et al., 2013). Indeed, they passed 39.2% of their time to watch left sections of the screen (LS, LM and EC (LS)) and 9.4% of their time to watch right sections of the screen (RS, RM and EC (RS)) comparatively to 30.5% and 7.7% Respectively for drivers in Romoser et al.'s study. This indicates that ambulance drivers had a greater scan of peripheral areas, providing them with a stronger sense of scanning hazardous areas outside their intended path of travel than the general public. During right turns, in comparison to a study with drivers of all ages (18 to 80 years old) (Bao & Boyle, 2009) that were found to scan the left-hand section of the road was looked at for 35% of the time and the right-hand section for only 1% of the time, compared with less than 1% of the time for our ambulance drivers and over 42% of the time respectively. These differences can be explained by the fact that the two right turns are not identical. In the Bao and Boyle (2009) study, drivers turned right at a stop sign in a cross intersection, whereas in our study, ambulance drivers turned right at an intersection without a stop sign, in an intersection with only one street on the right (t-shape intersection).

Practical Implications

This study is the first of its kind to investigate visual search patterns in ambulance drivers while they are driving. Our observations indicate that experienced ambulance drivers adapt their visual search strategies in proportion to the driving demands. Among our cohort of experienced paramedics, we noted longer fixation times, more frequent visual scanning, and a greater variety of visual search patterns while driving in more demanding contexts, suggesting adaptive strategies related to the detection of potential hazards around the vehicle. The findings from our cohort are consistent with previous research, indicating that novice ambulance drivers should perform similarly to other novice drivers and can also be effectively trained. By using an ambulance simulator for training novice drivers, for instance, we ensured consistency, comparability and safety between scenarios used. Based on results from experienced drivers, it is reasonable to assume that optimal visual search patterns and strategies can be taught and practiced within a simulator.

Although the impact of the ambulance simulator on drivers remains largely unexplored, a recent study conducted in Germany found no negative training effects and some positive outcomes, particularly a reduction in speed that did not adversely affect driving times to operational sites (Prohn & Herbig, 2020). Given the cognitive load and occupational stress related to ambulance driving tasks, assessing and training in managing this cognitive load and stress could help mitigate their negative effects (Malone et al., 2024). For example, police officers who can often be compared to ambulance drivers due to stress, workloads, fatigue, and declining professional well-being (Bevan et al., 2022; Zimmerman, 2012), can undergo either standard or advanced driver training, depending on their position (Dorn, 2005). Advanced training for police officers encompasses all the elements of standard training, supplemented by practical training in high-speed driving techniques to achieve a high level of general proficiency. Additionally, advanced training places greater emphasis on hazard awareness and maintaining visual contact with the target vehicle, while sharpening observation skills to anticipate potential dangers. Advanced training for police officers enables them to make more confident decisions about speed than drivers with standard training (Dorn, 2005). Standard-trained drivers tend to overestimate their abilities and rate their chances of being involved in a collision lower than drivers with advanced training, while standard drivers are more at risk of being involved in a collision than experienced drivers (Dorn, 2005). For this reason, advanced training for experienced drivers should perhaps be extended to all emergency drivers. According to recommendations based on the needs of police forces (Tiesman & Heick, 2014), it would be beneficial to offer more regular training in the use of ambulance driving. Video or simulator-based training could already help improve ambulance drivers' driving skills (Horswill et al., 2013). If this training were repeated over time with ambulance drivers, it would be expected to provide feedback on errors and improvements made by participants over time (Hua et al., 2016).

Future Research

Further studies are necessary to understand better the visual search and detection of road elements, particularly in comparing and documenting the peripheral vision of ambulance drivers across different situations and driving contexts. It would also be valuable to repeat these measurements with other first responders to determine if they share common visual search strategies, as well as whether these strategies are related to driving performance and safety issues. Additionally, there is an opportunity to utilize an oculometric system to lessen the workload associated with image-by-image analysis. It may be beneficial to explore potential enhancements to ambulance driving aids to improve visibility.

Study Limitations

The study involved a small sample size, and it would have been preferable to include a larger representation, particularly among a broader spectrum of driving experience (in terms of years (novice vs. experienced), as well as urban, suburban, and rural settings), as well as EMTs and firefighter drivers, to enhance the generalizability of the results. The authors exercise caution in making broad claims based on these findings, emphasizing that further research is necessary to validate these observations.

While simulations enable us to repeat and control driving conditions, it would also be beneficial to compare and confirm our results with a field study. Additionally, the simulation used was the same scenario for all participants, which introduces the possibility of bias from that protocol.

Manual extraction was conducted without validation by the oculometry system. However, this process followed the established best practices and recommendations for this type of protocol and data. The extraction was carried out meticulously by a research assistant under the supervision of experienced researchers. The authors acknowledge the potential risk of false-positive or false-negative errors occurring during this process.

CONCLUSION

The current study focused on documenting the visual search patterns of experienced ambulance drivers in relation to their work context and driving situations. The findings indicate that experienced ambulance drivers adjust their visual search strategies in response to driving demands. Specifically, when driving demand increases, drivers exhibit longer fixation times, more frequent scanning, and a greater variety of search patterns. It was suggested that these visual search strategies were adaptive and helped the driver detect potential hazards. The study also suggests that experienced ambulance drivers may use similar visual search strategies to those used by other experienced drivers, as demonstrated in the literature. These strategies can be enhanced through training, particularly by utilizing ambulance simulators that replicate urgent driving scenarios, thereby minimizing risks for ambulance drivers and other road users.

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APPENDIX A

Complementary data from average fixation time (in seconds) by driving situations related regions of interest (ROIs)

ROI	Percentile (th)	Driving Situations											
		1	2	3	4	5	6	7	8	9	10	11	12
	n	16	16	14	15	15	16	16	14	14	14	14	11
	Missing Value	0	0	2	1	1	0	0	2	2	2	2	5
LS	25	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.54	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.74	0.00	0.00	0.00	0.00	1.05	0.00	0.00
	75	0.00	0.00	0.08	0.20	0.87	0.00	0.00	0.00	0.00	2.10	0.00	0.30
LM	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	75	0.45	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.35	0.03	0.00	0.00
CS (LS)	25	0.00	0.00	0.00	0.00	0.35	0.00	0.18	0.00	0.00	0.39	0.15	0.21
	50	0.00	0.00	0.00	0.00	0.49	0.00	0.37	0.18	0.08	0.54	0.41	0.43
	75	0.00	0.37	0.28	0.13	0.67	0.33	0.49	0.34	0.32	0.62	0.55	1.00
CS	25	0.84	1.06	0.79	0.33	0.61	0.47	0.45	0.89	0.37	0.41	0.34	0.67
	50	1.68	1.85	0.86	0.42	0.91	0.58	0.52	1.02	0.56	0.58	0.45	1.01
	75	2.25	2.33	2.19	0.64	1.24	0.79	0.65	1.30	0.72	0.78	0.71	1.46
CS (RS)	25	0.00	0.00	0.00	0.37	0.23	0.43	0.22	0.00	0.29	0.00	0.37	0.15
	50	0.00	0.00	0.08	0.48	0.30	0.53	0.33	0.17	0.42	0.25	0.55	0.32
	75	0.05	0.17	0.54	0.82	0.38	0.67	0.40	0.42	0.97	0.36	0.74	0.49
RS	25	0.00	0.00	0.00	0.22	0.00	1.15	0.26	0.00	0.56	0.00	0.75	0.00
	50	0.00	0.00	0.00	0.33	0.22	2.18	0.69	0.00	0.80	0.00	1.19	0.10
	75	0.00	0.03	0.07	0.42	0.50	2.57	0.88	0.00	0.99	0.11	1.52	0.30
RM	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00
DO	25	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.48	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00
	75	0.56	0.43	0.00	0.00	0.00	0.00	0.00	0.37	0.15	0.00	0.00	0.30
CT	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.00
	75	0.00	0.00	0.18	0.00	0.30	0.00	0.53	0.65	0.58	0.00	0.00	0.00
IND	25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	75	0.00	0.00	0.05	0.17	0.07	0.00	0.13	0.03	0.00	0.00	0.00	0.10

Note: CS: central screen, CS(LS): left section of central screen, CS(RS): right section of central screen, CT: command terminal (light and siren control), DO: area with the dashboard and the odometer, LM: left mirror, LS: left screen, RM: right mirror, RS: right screen.

APPENDIX B

Complementarity data from the average number of regions of interest changes related to regions of interest (ROIs)

Percentile (th)	Driving Situations											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
n	16	16	14	15	15	16	16	14	14	14	14	11
Missing Value	0	0	2	1	1	0	0	2	2	2	2	5
25	3.25	3.00	4.00	7.00	13.00	7.00	9.00	4.75	*7.75*	*9.00*	*8.00*	*7.00*
50	4.50	4.50	6.50	10.00	23.00	7.00	13.00	6.50	*16.50*	*11.00*	*11.50*	*11.00*
75	7.00	6.50	8.00	12.00	25.00	10.00	18.75	9.25	*20.75*	*16.00*	*14.00*	*13.00*