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THE INFLUENCE OF DISTRACTORS ON VISUAL ATTENTION AND SAFETY-RELATED BEHAVIORS WHILE DRIVING

Summary. Safe participation in road traffic requires the effective monitoring of one's surroundings and adequate reactions to stimuli. A particular challenge for drivers is the presence of distractors, which can limit the selectivity and shifting of attention, thus reducing situational awareness. The aim of this study was to analyze the influence of different types of distractors on drivers' visual attention and their behavior in situations requiring sudden reactions. The study was conducted in a simulator environment including two scenarios: driving in a convoy and autonomous driving with the need to take control of the vehicle. The experiment involved 95 active drivers (M = 34.84, SD = 12.09). Two types of distractors were introduced: cognitive (n-back task) and visual-manual (SURT). The analysis of the drivers' behavior showed that distractors significantly reduced the number of glances at the road, especially in the visual-manual condition, in which drivers monitored their surroundings less frequently and reacted more slowly to emergencies. In the conditions of sudden braking, the percentage of glances at the road was significantly lower when distractors were present. Moreover, cognitive distractors affected the shifting of glances to less important areas, while limited visibility due to fog increased the number of glances at the road. The results highlight the significant role of cognitive load in the driving process and underscore the importance of reducing distractions to enhance road safety.

1. INTRODUCTION

The ability to concentrate on the right stimuli from the environment is necessary to ensure safe participation in road traffic, as is an adequate reaction based on the information that the correct identification of these factors provides. In the process of detecting stimuli that condition safe participation in road traffic, awareness and concentration are necessary; therefore, the ability to focus on the right elements is required. This is particularly important when there are many distracting factors in the environment. Analyses confirm that distractors appearing during driving have a significant impact on our road behavior [1, 2]. Selective attention enables us to focus on elements that are significant from the perspective of a safe maneuver and disregard what is less important at a given moment. Selectivity and attention shifting allow us to shift our attention from the target stimulus to other elements and return to the initial stimulus if it significantly affects the safety of the maneuvers being performed. Distractors can appear in the field of vision and divert attention by utilizing other information detection channels. According to existing studies, tasks that require visual attention cause the eyes to divert from the road, and tasks that require special mental engagement, such as cognitive tasks, are particularly hazardous. Analyzing their impact on safe functioning on the road is an important element of accident prevention.

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2. DISTRACTORS IN THE ROAD TRAFFIC

Distractors, as factors that distract drivers' attention, can have a significant impact on driving safety, primarily due to limiting drivers' ability to effectively process information from the road environment and respond adequately to hazards. Distraction is one of the main factors causing road accidents, sometimes compared to driving under the influence of alcohol [3, 4]. The elements distracting drivers from aspects related to safety can be internal (e.g., experienced emotions, stress factors, psychophysiological factors) or external (e.g., advertisements, other vehicles, weather conditions) [5]. Distractors can also be classified as those that refer to aspects of the functioning of cognitive and manual processes.

Cognitive distractors are situations in which the driver is focused on something other than driving, such as a phone conversation or using a GPS device. Studies have shown that phone conversations (even with a hands-free set) increase reaction time and increase the risk of an accident [6, 7]. Visual distractions, which also draw the driver's eyes away from the road, such as watching a navigation screen, reading text messages, or looking at advertisements, may pose a particular threat. Eye-tracking experiments have shown that looking away from the road for more than two seconds significantly increases the risk of an accident [8]. Drivers who are distracted scan their surroundings less effectively, which can lead to so-called "inattentional blindness" [9]. It has also been shown that using a mobile phone slows down reaction time by about 0.25–0.5 seconds, which, in practice, can mean an additional 5–10 meters of braking distance at a speed of 100 km/h [4]. In addition, a significant impact on safety is also observed in the case of auditory stimuli. Phone calls, loud music, or conversations with fellow passengers can extend reaction time and reduce the ability to detect warning signals [10].

It is worth noting that there are also distractors that cause the hands to be taken off the steering wheel, such as adjusting the radio, using devices, or eating. Studies have shown that manual distractors (e.g., writing text messages) increase the probability of an accident by up to 23 times [11]. These types of distractions cause more frequent lane crossing, speed changes, and sudden braking, which increase the risk of collisions [12]. Analyses show that novice drivers are more susceptible to the influence of distractors than experienced drivers because their ability to divide attention and manage cognitive resources is less developed [13].

3. THE ROLE OF VISUAL ATTENTION IN THE PROCESS OF RESISTANCE TO DISTRACTORS

Visual impressions provide the driver with information about the position of their vehicle and potential hazards. In this case, the decision-making process is mainly based on the ability to process a large amount of information within the driver's field of vision. Noticing signs, objects, events, and people while driving requires high perceptual skills, as well as the ability to focus on information that is important from the safety perspective. An important role is played by the ability to judge a distance and distinguish shapes (also in the dark), sensitivity to glare, and correct discrimination of colors, among others. Safe driving involves, among other things, the sufficiently fast and accurate noticing and isolation of events that are important from the point of view of road safety [14]. However, based on sensory aspects alone, the basic elements for perceptual mechanisms are visual attention and its resistance to distracting elements. Visual attention is not a homogeneous cognitive process because it is composed of many mechanisms with different functional features [15].

Not only is visual attention important, but so is resistance to distractors. From the moment of noticing a stimulus to braking, the brain engages in many processes at the neuronal level. Each additional element constituting a distractor can cause changes in perception processes that are so important for safety that they can be considered crucial. All these elements disrupt the processes of deliberate collection of visual information and make previously developed models of action outdated. Therefore, it is necessary to create a new strategy for the proper course of the attention process [16]. In inexperienced, tired, or elderly drivers, the selective visual perception system overload may occur if many visual stimuli are present in some road situations in short intervals. This results in important visual information being omitted as the driver redirects their attention to distractors [17], which has a decisive impact on functioning on the road.

Previous studies have shown that visual and auditory distracting factors affect the perception of the surroundings while driving. In the study by Samuel et al. [18], it was noted that drivers who were presented with an additional task (a secondary visual task requiring them to take their eyes off the road and look at elements inside the vehicle) often did not monitor the surroundings for hidden hazards (the view of an approaching vehicle on a collision course was blocked by a parked truck) immediately after completing the task. Recarte and Nunes [19] examined the effect of performing cognitive tasks (verbal and spatial-visual) on drivers' eye fixations while driving and observed a reduction in the drivers' vertical and horizontal field of vision. Moreover, during the spatial imaging task, fixations on this stimulus were longer, and the frequency of looking at mirrors and the speedometer decreased.

In another experiment [20], drivers performed cognitive tasks without having to take their hands off the steering wheel while driving in city traffic. The researchers noticed that drivers spent more time looking centrally ahead and less time observing peripheral areas. Drivers also limited or stopped monitoring instruments (e.g., the speedometer) and mirrors. This affected driving control, and during the most difficult cognitive tasks, drivers were more likely to brake suddenly. These studies confirm the importance of perception and attention processes for safe functioning in road traffic and indicate the need to analyze these conditions and search for preventive possibilities.

For several years, visual attention and transfer of control in automated vehicles have been explored. It has been shown, among other things, that drivers' behavior during the transfer of control is affected by, for example, secondary tasks performed while driving [21, 22].

Based on the above analyses, it was assumed that visual attention depends not only on individual factors but also, to a large extent, on the situation and road conditions. It was expected that when it was necessary to perform a sudden braking maneuver and/or take control of the car, drivers would react differently depending on the type of distractor. It was also checked how drivers observed the road surroundings and the area of control devices depending on the condition and research sample. Previous analyses in this regard show the influence of so-called secondary tasks performed while driving on the process of taking control of the vehicle in necessary conditions (transfer of control) [23, 21, 22, 24, 25]. It was also expected that drivers would direct their eyesight away from the road and redirect their attention to other elements. Additionally, it was assumed that under distraction conditions, drivers may make errors that may result in road accidents.

4. RESEARCH METHODOLOGY

The present study involved 95 people aged 19–69 (M = 34.84, SD = 12.09), including 47 (approx. 50%) women. All participants were active drivers who had been driving for 2–45 years (M = 13.91, SD = 10.31). The study was conducted at the Transport Psychology and Driving Simulators Laboratory of the Motor Transport Institute in a simulator environment. Individual variables were measured based on indicators obtained from a driving simulator (direct indicators of driver behavior, including the degree to which individual pedals were pressed and the use of turn signals; Fig. 1). Visual activity indicators were recorded using a Smart Eye Pro device located in the vehicle cabin, which provided information on the head position and direction of gaze in three-dimensional space (3D). The visual tracking process was conducted using the subject's personal profile, and individual calibration was performed for each participant before the experiment. The places of visual focus during individual drives were analyzed, as were the reaction in sudden braking conditions and the time and manner of taking control in distraction conditions.

An experiment was developed using driving simulators and research equipment to measure variables to analyze visual attention and its dependence on potential distractors while driving a vehicle. Two research scenarios were developed: a route in a convoy and driving in autonomous conditions (Fig. 2). In the first scenario, drivers were tasked with driving in a convoy of moving vehicles; in the second, driving took place on a section of a motorway and the subject's task was to take control of the vehicle in given road situations. Distractors were planned to be introduced in each of the conditions. In the convoy (1), these were vocal distractors in the form of an auditory-vocal task, the so-called n-back (delayed digit recall task), which aims to induce cognitive load by engaging the driver's working (short-term) memory. The task consisted of listening to the sequences of numbers and recalling the appropriate number according to the level of difficulty (0-back, 1-back, and 2-back). For the 0-back task, the participant had to say the last number heard. In the 1-back task, the participant said the penultimate number heard, and in the 2-back task, he repeated the digit heard as the third from the end.

Fig. 1. AS1200-6 passenger car simulator. Source: Motor Transport Institute

Fig. 2. View of the simulation area where the research scenarios were conducted. Source: Motor Transport Institute

The second scenario involved a visual distractor in the form of the SURT task. The SURT method is a visual distractor that additionally engages the driver manually (the task involves searching for the largest circle on a touchscreen device out of a dozen or so that appear on the screen). The level of difficulty was gradually increased. During this task, the preceding vehicle suddenly braked, forcing the driver to react.

In autonomous driving (2), two distractors were introduced: fog (limiting the driver's ability to observe their surroundings) as an external distractor and the SURT task. The subjects performed five unexpected braking trials under the following conditions: without a distractor (two brakings), while performing the 2-back task, while performing the 0-back task, and while performing the SURT task.

Additionally, in the first scenario, during the 2-back task, the preceding car suddenly braked, forcing the driver to react. After resuming driving, the driver performed the 0-back task again, during which sudden braking occurred again. In Scenario 2, the subjects had to take control of the vehicle three times.

5. RESULTS

In the first stage of the analysis, it was examined which elements the drivers focused their attention on while driving and whether their focus depended on the conditions and distractors introduced in each scenario. While driving in the convoy, the proportion of gazes in different directions was checked. The analyses showed that the participants differed in terms of the proportion of glances at the screen, depending on the conditions, $F(5,88) = 305.87$, $p < .001$, $p = .77$. Post hoc tests with Bonferroni correction showed that in the SURT conditions, the proportion of glances at the screen was significantly lower than in all other conditions ($p < .001$). In addition, the 0-back conditions differed significantly from the conditions without distractors ($p < .022$). The proportion of glances at the screen based on the driving conditions in the convoy is presented in Fig. 3.

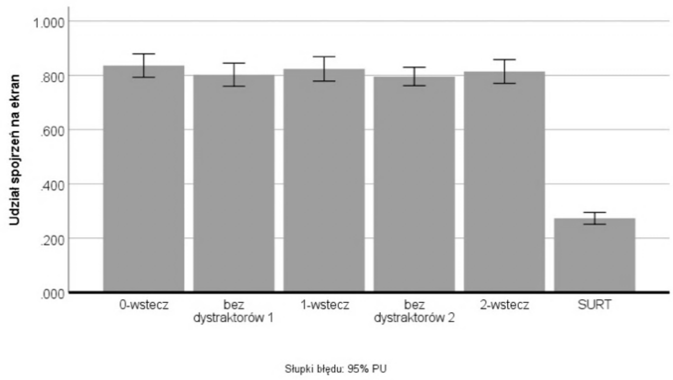

Fig. 3. The proportion of glances at the screen based on the driving conditions in the convoy

The proportion of glances at instruments was also dependent on the conditions, $F(4,88) = 21.89$, $p < .001$, $eta2p = .19$. The highest proportion of glances was observed in the control conditions (without distractors). This means that drivers not subjected to distractions were more likely to check the instruments (e.g., speedometer). The control conditions did not differ from each other, but they did differ from the other driving conditions in the convoy ($p < .001$). The conditions with distractors did not differ from each other in terms of the proportion of glances at the instruments. The averages obtained by drivers are presented in Fig. 4.

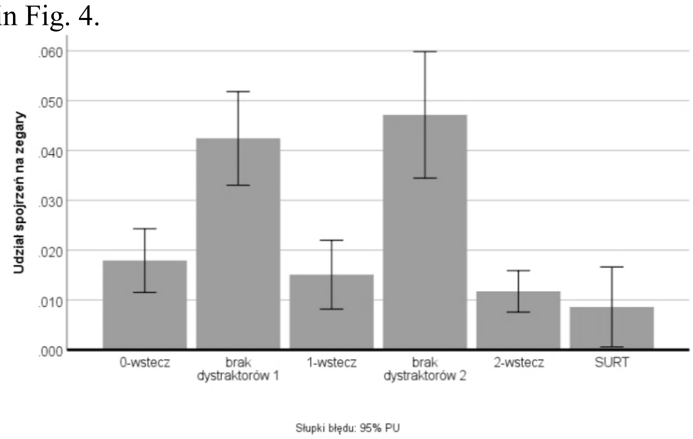

Fig. 4. Proportion of glances at the instruments depending on driving conditions in a convoy

Conditions also differentiated the proportion of glances at the tablet, $F(4.88) = 570.79$. $p < .001$, eta2p = .86. In all conditions, except SURT, it was close to zero. Hence, all the differences between these conditions and the others were significant ($p < .001$), while differences between the other conditions were statistically insignificant. The situation was similar in the case of the proportion of glances at the radio – the conditions differentiated this indicator, $F(4,88) = 21.12$, $p < .001$, eta2p = .19, and the differences in post-hoc tests reflected those obtained for glances towards the tablet, as differences were observed between the SURT conditions and the other conditions, as well as between the 0-back/1-back/2-back conditions and the conditions without distractors.

The research conditions also differentiated the way of controlling driving in the form of glances at the left mirror, $F(4,88) = 9.01$, $p < .001$, eta2p = .09. The lowest proportion of glances in this direction was noted in the SURT condition, followed by the 1-back and 0-back conditions, and the highest was observed in control conditions 2 and 1. Accordingly, the SURT conditions differed significantly from the other conditions ($p < .001$), except for the 1-back condition. The control conditions did not differ from each other, as in the 0-back and 2-back conditions. On the other hand, the 0-back and 1-back conditions differed from control conditions 1 and 2, and the 2-back conditions only differed from control condition 2. The means are presented in Fig. 5.

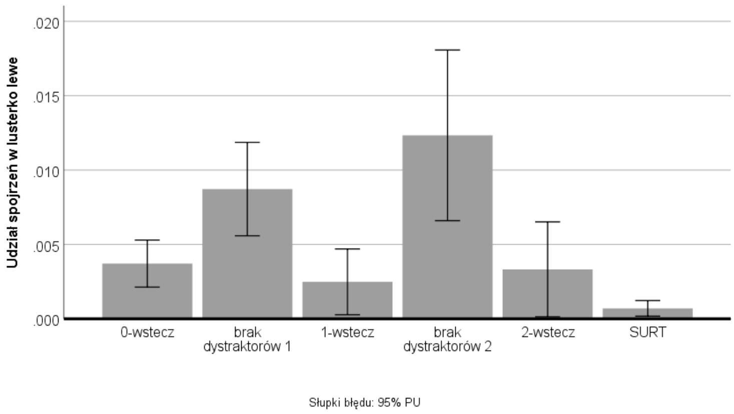

Fig. 5. Proportions of glances at the left mirror depending on the driving conditions in a convoy

Concerning the proportion of glances at the central mirror, an effect of the study condition was also noted, $F(4,88) = 9.62$, $p < .001$, eta2p = .09. The lowest proportion of gazes in this direction was observed for the 2-back condition, followed by the 1-back condition and then the 0-back condition. The proportion of gazes at the central mirror in both the control conditions and the SURT condition was higher and similar. The SURT condition differed only from the 2-back and 1-back conditions, and the two control conditions did not differ from each other. It also turned out that the 2-back condition and the 1-back condition differed from the 0-back condition. The control conditions did not differ from each other, but they did differ from the 1-back and 2-back conditions. The means are presented in Fig. 6.

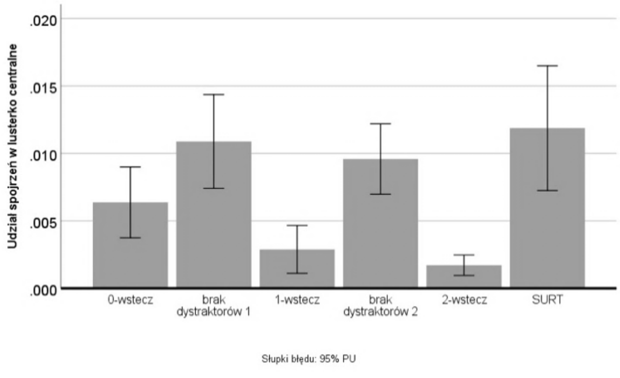

Fig. 6. Proportion of glances at the central mirror depending on driving conditions in a convoy

The analyses also show that the remaining glances at the front of the car between the screen above and the instruments below, as well as between the tablet and the automation console (looking forward), depended on the conditions, $F(4.88) = 24.86$, $p < .001$, $eta2p = .21$. The highest proportion of glances forward was observed in the SURT condition, and these conditions differed from the others ($p < .001$). The other conditions did not differ in this respect.

Differences between conditions also appeared in the case of directing a glance at the right door, $F(4.88) = 33.25$, $p < .001$, $eta2p = .26$. The proportion of glances in this direction was close to zero in all conditions (especially in the 0-back condition), but in the SURT condition, it was significantly higher than in the others ($p < .001$). The conditions did not significantly differentiate the proportion of glances around (looking at the screen to the sides, not at the road in front), at the right mirror, at the left door, and in an unspecified direction.

The analyses also examined the directions of drivers' gazes in a situation of sudden braking while driving in a convoy (Scenario 1). Most often, the subjects focused their gaze on the screen (i.e., the road in front of the vehicle), regardless of the event, as follows: 81% of glances in the 2-back conditions, 87% in the 0-back conditions, 93% in the conditions without distractors, and 50% in the SURT conditions. In the SURT conditions, due to the task being performed, the subjects also often returned their gaze to the area of the tablet on which the task was presented (22%). The proportion of glances in other directions was minimal (apart from looking at the sides of the screen in the SURT and 2-back conditions, for which the proportion of glances was 10–11%, and even zero in the case of some directions.

The analyses show that the proportion of glances at the screen (road in front of the vehicle, cars, etc.) varied depending on the conditions, $F(3,90) = 69.91$, $p < .001$, $eta2p = 43$. The shortest time spent gazing at the screen was in the SURT condition, followed by the 2-back condition, then the 0-back condition. The longest time drivers spent gazing at the screen was observed in the no-distractors condition. All post-hoc tests were significant, with p-values ranging from < 0.001 to .032. The conditions also differentiated the way in which drivers observed the field in front of the car—the remaining glances at the front of the car, between the screen above and the instruments below, and between the tablet and the automation console, $F(3,90) = 5.12$, $p = .010$, $eta2p = .05$. Subjects looked forward most frequently (compared to gaze in other directions) in the SURT condition, less frequently in the 2-back and 0-back conditions, and least frequently in the control condition. Differences in post-hoc tests were observed between the baseline conditions: SURT ($p < .001$) and 2-back ($p = .019$). Differences between the 2-back and 0-back conditions, the 2-back and SURT conditions, and the 0-back and SURT conditions were not significant.

The drivers also differed in the proportion of time spent looking at the sides of the screen (e.g., the roadside area), $F(3,90) = 9.52$, $p < .001$, $eta2p = .09$. In the 2-back and SURT conditions, participants had the highest proportion of gaze to the sides of the screen; there were no differences between these conditions ($p > .64$), but both were significantly higher than in the other conditions (p-values ranged from <.001 to .039). Furthermore, in the 0-back condition, the proportion of gazes to the sides of the screen was higher than in the control condition ($p = .022$) (in control condition was as the lowest). The time spent looking at the tablet also depended on the conditions, $F(3,90) = 78.38$, $p < .001$, $eta2p = .46$. In the 0-back condition, participants directed almost no gazes to the tablet compared to other areas. A very small proportion of gazes in this direction was also noted in the 2-back condition and in the absence of distractors. Only in the SURT condition was there a significantly greater proportion of gazes at the tablet than in the other conditions ($p < .001$), which did not differ. An identical situation was observed in the case of the proportion of glances at the radio. The observed differences between conditions, $F(3,90) = 10.99$, $p = .001$, $eta2p = .10$, resulted exclusively from the higher proportion of looking at the radio in the SURT condition than in the other conditions, with p-values ranging from .001 to .002. However, the proportion of looking at the radio, even in the SURT condition, was relatively small ($M = .005$).

The conditions did not significantly differentiate the proportion of glances at the instruments ($p > .48$), the left mirror ($p > .68$), the central mirror ($p > .20$), the left door ($p > .61$), or in an unspecified direction ($p > .26$). On the other hand, the proportion of glances at the mirror and the right door was negligible. In the second stage of the analysis, the proportion of gaze data at various objects in the simulator cockpit based on the condition and trial while driving in a motorway environment (Scenario 2 - automatic) was determined. The three trials conducted for each planned condition also differentiated the way the subjects observed the road.

The proportion of glances at the screen (road, cars in front) depended on the test, $F(2,81) = 35.41$, $p < .001$, eta2p = .30, and on the condition, $F(2,81) = 5.45$, $p = .006$, eta2p = .119. The interaction of the test and condition was not significant ($p > .43$). Post-hoc tests showed that the proportion of glances at the screen was most frequent in the third test, as it was greater than in the first test ($p < .001$) and the second test ($p = .007$). Also, the proportion of glances at the screen in the second test was greater than in the first ($p < .001$). In the subsequent tests, the number of glances at the screen was higher (Table 1).

Table 1

Mean proportions of glances at the screen based on the test

Test	M	SD	95% confidence interval	
			Lower limit	Upper limit
1	.493	.026	.442	.545
2	.673	.026	.622	.724
3	.750	.026	.697	.802

The proportion of glances at the screen in the foggy driving condition was higher than in other conditions ($p = .002$) and in the absence of a distractor ($p = .015$). The mean proportions of glances at the screen based on the condition are presented in Fig. 7.

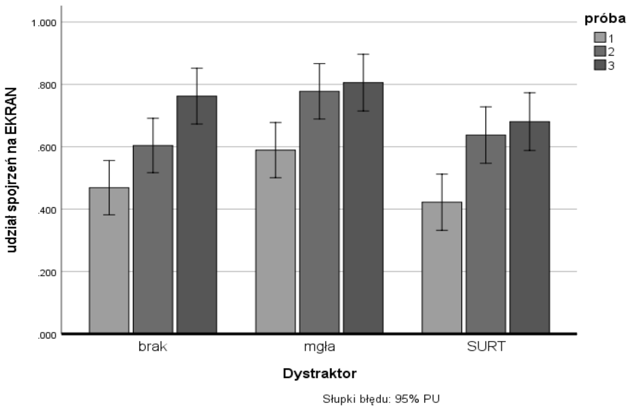

Fig. 7. Average (with 95% trust ranges) proportions of gazes at the screen in the simulator cockpit based on the condition and the test

In the case of looking at the instruments (e.g., speedometer), the analyses showed that the proportion of glances at this area was also different depending on the test, $F(2.81) = 35.01$, $p <.001$, eta2p = .30. Post-hoc tests showed that the proportion of glances at the instruments in the first test was higher than in the second ($p <.001$) and third tests ($p <.001$), and the proportion of glances at the instruments in the second test was greater than in the third test ($p = .002$). Also, the observation of this area was not dependent on the condition, but the p-value was at the statistical tendency level, $F(2.81) = 2.78$, $p = .067$, eta2p = .06. Post-hoc tests showed that the conditions of travel without distractors were significantly different from the travel conditions with the SURT task ($p = .025$). Without distracting stimuli, the glances at the instruments were more frequent than in the SURT condition.

The effect of the test and condition interaction was nearly statistically significant, $F(4.81) = 2.65$, $p = .052$. Post-hoc tests showed that in the first test, all conditions differed significantly ($p < .020$), while the participation of glances at the instruments was highest in the absence of distractors, then in the fog, and lowest when performing SURT. In the second test, the proportion of glances on the instruments was highest in the absence of distractors and differed significantly from the other two conditions ($p < .004$), which did not differ from each other. In the third test, the situation looked similar to the second test (i.e., there was a difference between the conditions without distractors, which had the largest proportion of glances at the instruments, and the other two remaining conditions (p <.002) but not between the conditions with fog and SURT.

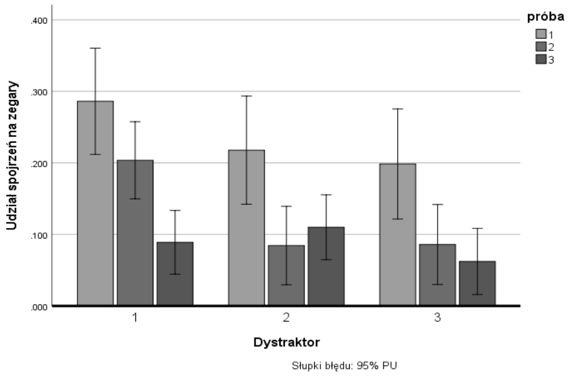

Fig. 8. Average (with 95% trust range) proportions of glances at the instruments in the simulator cockpit depending on the condition (distractor: 1 – none, 2 – fog, 3 – SURT)

The participation of glances at the tablet in Scenario 2 was analyzed successively. The test did not affect the number of gazes at the tablet (p >.17), but the conditions shaped this variable, F (1.81) = 13.54, P <.001, eta2p = .25. It was different in the case of SURT. Post-hoc tests revealed that the conditions from SURT generated a higher proportion of glances at the tablet than the conditions without distractors (p < .001) and driving conditions in fog (p < .001). However, driving conditions in fog and driving conditions without distractors did not differ in this respect. The proportion of glances at the radio panel in the car, including the automation console (e.g., flashing warning diodes, which signaled a request to take control), was also analyzed. The results show that the participation of glances at the radio depended on the test, F (2.81) = 22.29, p <.001, eta2p = .216. Post-hoc tests indicated that the proportion of gazes at the radio was significantly greater in the first test than in the second (p <. 001) and third tests (p <.001), as well as in the second test than in the third (p = .002). The proportion of glances at the radio was not dependent on the condition or the interaction of the condition with the test.

It was also analyzed how the driver controlled the area outside the car depending on the research condition (using the example of glances at the left mirror). Depending on the test, the proportion of glances at the left mirror was different, F (2.81) = 4.16, p = .018, eta2p = .05. Post-hoc tests showed that ~~it~~ the proportion of glances at the left mirror was smaller in the first test than in the second (p = .009) and the third tests (p = .016), but it was not different in the second and third. Analyses also showed that the frequency of glances at the left mirror varied depending on the test condition, F (2, 81) = 3.33, p = .041, Hp^2 = .076. Post-hoc tests showed that the number of glances at the left mirror was greater in SURT conditions than in driving conditions with fog (p = .013).

However, the respondents did not differ in the proportion of glances at the central mirror depending on the test or condition. Similar conclusions were drawn regarding the gazes at the right mirror and the areas of the right and left doors. In turn, the analysis of the proportion of glances at the front part of the car, between the screen above and the instruments below, and between the tablet and the automation console showed that the proportion of glances at the front part of the car varied depending on the test, F (2.81) = 9.09, p <.001, eta2p = 10. Post-hoc tests showed that the number of looks at the front part of the car was higher (and the highest of all three tests) in the first test than in the second (p = .035) and third tests (p <.001). It was also higher in the second test than in the third test (p = .025). The conditions (or their interaction with a test) did not differentiate the participation of glances at the front of the car.

Scenario 2 was used to investigate how distractors affect drivers' functioning in road traffic, particularly in terms of their influence on control transitions. Analyses were conducted using multiple H Kruskala-Wallis non-parametric tests. Pairs of control transition methods were compared to determine which method was more commonly used. Distractors had the most significant effect on control transition in Test 3 when comparing vehicle-initiated automated braking with driver-initiated lane change (H = 9.105, p = .011)) and when comparing driver-initiated lane change with driver-initiated taking control (H = 7.63, p = .022). The impact was also noticed in Test 1 when comparing vehicle-initiated automated braking with the frequency of driver-initiated control transition (H = 9.34, p = .009). At the level of statistical trend, a significant effect of distractors was observed in Test 2 when vehicle-initiated automated braking and driver-initiated control transition were compared (p = .09).

U Mann-Whitney's post hoc tests showed that in Test 1 the conditions without distractors and those with fog significantly differed in terms of the frequency of automated braking and taking control of the vehicle (U = 299, z = -2.87, p = .004). While in the conditions without distractors, participants took control much more frequently (28 cases) than automated braking occurred (two cases), whereas, under foggy conditions, the frequency of automated braking increased (11 instances compared to 18 instances of taking control). Interpreting the results for Test 2, based on post hoc comparisons, it was noticed that the conditions without distractors and those with fog differentiated participants' responses in terms of automated braking and taking control (U = 319, z = -2.18, p = .029). When no distractors were introduced, participants more often took control of the vehicle (26 times) than automated braking was triggered (three times). However, when driving in foggy conditions, automated braking was more frequent, resulting in a more balanced ratio between vehicle- (10 cases) and driver-initiated interventions (19 cases). Post hoc tests for Test 3 indicated a significant difference in the type of response depending on the conditions (U = 161, z = -2.69, p = .007). During foggy conditions, participants did not change lanes but instead took over control of the vehicle (0 cases of lane change versus 19 cases of control transition). In good weather conditions, lane changes were not as rare (eight vs. 17). In Test 3, the ratio of automated braking and lane changes also varied depending on the presence of a distractor (U = 25.00, Z = -3.00, p = .003). While the ratio was relatively balanced without a distractor, under foggy conditions, all events resulted in automated braking. This pattern also differed between foggy conditions and those involving the SURT distractor (U = 35, Z = -2.06, p = .039); in the SURT condition, automated braking and lane changes occurred with similar frequency.

6. DISCUSSION

The conducted test aimed to determine the impact of various driving conditions and the presence of distractors on how drivers direct their attention and analyze their behavior in situations requiring a sudden reaction. The results provide relevant information on the strategy of drivers' attention and the consequences of the presence of distractors in the context of road safety. Studies indicate significant differences in how drivers monitor their environment depending on the degree of cognitive load. These results align with previous research on the impact of distraction on drivers' attention and situational awareness [26, 3]. The analyses conducted to date have shown that tasks requiring visual attention are particularly detrimental to control over the vehicle, causing the eye to look away from the road, as well as tasks that require special cognitive commitment, while auditory tasks cause less dispersion [27].

Studies have shown that in the SURT condition, drivers are significantly less likely to look at the screen (i.e., the road in front of the vehicle) than in the other conditions. The limited number of glances at the road when performing an additional cognitive task confirms previous reports, according to which cognitive load leads to so-called "hazard blindness" (i.e., difficulties in noticing key stimuli in the driving environment) [28]. A similar effect was observed in the case of glances at the cockpit instruments. Specifically, drivers in the control condition (without distractors) checked the vehicle indicators more often, while in the condition with distractors, the number of glances at this area was lower. This is consistent with Kahneman's (1973) [29] limited attentional resources model, which suggests that when cognitive resources are absorbed by an additional task, monitoring the surroundings becomes less effective.

The analysis of glances at mirrors revealed that the conditions differentiated the proportion of glances directed at the left and central mirrors. In the SURT condition, drivers checked the left mirror less often, which may lead to reduced situational awareness and limited ability to make appropriate decisions in road traffic. These results align with the research by Harbluk et al. [20], who demonstrated that attentional load reduces the number of glances at mirrors and other elements used for monitoring the surroundings.

Additionally, it was noted that drivers in the SURT condition looked at the tablet and radio more often, indicating that performing the cognitive task led to greater concentration on these elements and, consequently, to distraction from the situation on the road. This effect corresponds to previous studies on the impact of interacting with mobile devices while driving, which have shown that looking at the screen of a phone or multimedia system significantly increases reaction time and the risk of a collision [7, 30].

Some of the most significant findings of the study pertain to the behavior of drivers in emergencies. During sudden braking, drivers in the control condition focused their gaze on the road almost 90% of the time, whereas in the SURT condition, this percentage was only 50%. This suggests that a high cognitive load may lead to delayed reactions in situations that require immediate attention. This is consistent with Strayer et al. [3], who found that cognitively demanding interactions reduce the effectiveness of reactions to sudden hazards on the road. It is also worth noting that in the 2-back condition, drivers also looked more often to the sides of the screen instead of focusing on the road. This suggests that working memory load also affects how the driver monitors the surroundings, although this effect was less pronounced than in the SURT condition. Similar results were obtained by Lee et al. [31], who found that tasks involving working memory reduce drivers' ability to monitor the dynamic traffic situation.

The results in the motorway environment showed that the proportion of glances at the screen increased in subsequent trials. This may be due to adaptation to the experimental conditions and increased concentration on the road situation. This effect is consistent with Fuller's [32] research, which suggests that experience and exposure to a given scenario can affect drivers' perceptual strategies. Another significant result was the more frequent occurrence of gaze shifting to the road in foggy conditions. This may indicate a greater need to monitor the situation in difficult weather conditions. Tivesten et al.'s (2015) [33] research showed that limited visibility increased the number of gazes at the road at the expense of monitoring vehicle indicators.

The final aspect of the analysis was the influence of distractors in which the driver took control of the vehicle. In foggy conditions, drivers were more likely to rely on automated braking rather than taking control of the vehicle themselves. This suggests that limited visibility affects the decision-making strategy – drivers may trust the assistance systems more than they risk misjudging the situation [34]. Interesting results were obtained in the third test, where the distraction-free condition showed that drivers were more likely to choose active control than in foggy conditions. This may mean that distractors reduce the willingness to actively participate in driving, which has important implications for the design of driver assistance systems.

7. PRACTICAL IMPLICATIONS AND LIMITATIONS OF THE STUDY

The results have important implications for road safety. Firstly, they confirm that distractors, such as the SURT task, significantly reduce drivers' ability to monitor their environment and respond to emergencies. These results emphasize the need to limit the number of distractors while driving and to design assistance systems that minimize the risk of distracting the driver from the road situation. Driver education, which involves training on the awareness of hazards associated with distractors as well as new technologies (driver assistance systems), can improve perceptual habits and reduce the effects of distraction [5].

One of the limitations of the study is the laboratory nature of the experiment – the simulator conditions, despite being highly realistic, may not fully reflect the dynamics of real driving. Furthermore, the study did not consider the long-term effects of drivers' adaptation to distractors.

8. CONCLUSIONS

The results provide important insights into the impact of cognitive load on how drivers monitor their surroundings and respond in emergencies. Studies have shown that distractors significantly affect the way drivers direct their attention, which may have consequences for road safety. Cognitive load resulting from engaging in additional activities and responding to distractors reduces the number of glances at the road, limits monitoring of the surroundings, and may affect the way decisions are made regarding taking control of the vehicle. Distractors have a significant impact on driving safety, leading to delayed reaction times, poorer scanning of the surroundings, and loss of vehicle control. Studies indicate that cognitive, visual, manual, and auditory distractors increase the risk of collisions. Reducing their impact requires driver education, introducing legal regulations, and using modern safety-supporting technologies. Drivers performing additional cognitive tasks paid less attention to the road, checked their mirrors less often, and showed less readiness to take control of the vehicle in an emergency. The results may be useful in designing driver assistance systems that minimize the negative impact of distractions and support optimal decision-making in road traffic.

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