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DIFFERENT FORMS OF ATTENTIONAL DISTURBANCES INVOLVED IN DRIVING ACCIDENTS

J. HOEL¹, M. JAFFARD¹, C. BOUJON², P. VAN ELSLANDE¹

1 INRETS-MA - Chemin de la Croix Blanche 13300 Salon de Provence - FRANCE

2 Université d'Angers - Maison des Sciences Humaines, 5 bis Boulevard Lavoisier 49045 Angers - FRANCE

Attentional processes are necessary for any complex activity, such as driving. When a driver's attention is not optimal, driving errors can arise. The aim of this study is to highlight the involvement of attentional problems and their weight in accident production, using data from in-depth accident analyses. Three attentional disturbances are distinguished according to the task that competes with the driving activity: inattention, attention competition and distraction. Inattention is the defect most frequently represented (74%) compared with attention competition (18%) and distraction (8%). Overall, attentional disturbances mainly lead to detection failures (44.7%). In more than half of the cases, other factors are required for a driving error to emerge. The interest of studying human failures linked to attentional disturbances is that it provides a definition of driver's needs in terms of assistance, thus identifying which systems are the most relevant and, on the contrary, which might reduce the attention capacities required for driving.

1 INTRODUCTION

Attentional processes play an essential role in the driving activity. The function of attention can be defined as the “control, orientation and selection by a person of one or several forms of

activities during a period of time that cannot be maintained for long” [1]. It is not only used to select information relevant to the driving situation and to inhibit irrelevant ones, but also to manage various tasks performed simultaneously by the driver. Indeed, driving is a complex activity that involves the implementation of many tasks necessary for its successful achievement: navigation, vehicle control and hazard identification [2]. Moreover, in addition to the tasks underlying driving, it is common for a driver to perform additional tasks unconnected to the primary activity. These include tuning the radio, talking with a passenger or just getting lost in one’s thoughts. Stutts et al. [3] showed that, even if discussion with another passenger is excluded, drivers perform a potentially distracting activity 16% of the effective driving time. Furthermore, with the introduction of new technologies into the vehicle, potentially distracting activities continue to increase. In other terms, the driving activity places the driver in a situation of attentional sharing all the time, whether while performing tasks inherent to driving or secondary tasks.

Many studies have shown that attention defects are one of the most important explicative elements for accidents. For example, for Stutts et al. [4] at least 25% of police-reported crashes involve some form of driver 'inattention'. Sussman et al. [5] estimate that inattention is responsible for 35 to 50% of accidents. However, attention disturbances deal with phenomena that can be quite varied and the variation in the results found in the literature reflects this. Indeed, the involvement of attention problems varies widely from one study to another: 25-78%! One possible explanation for this variability is the frequent confusion between attention problems and problems of vigilance. Indeed, in many studies, drowsiness is considered as a subcategory of "inattention" as well as distraction (e.g. [4], [6], [7]). Glase and Ellis even consider alcohol and drug use as an internal distraction in the vehicle [8].

In Psychology, vigilance and attention processes are clearly distinguished, the first referring to the individual’s level of alertness (related to fatigue, drugs, psychotropic substances) and

the latter to cognitive ability. In accident analysis, the importance of separating these two processes, as far as the failures to which they lead, has been emphasized by Van Elslande, Jaffard, Fouquet and Fournier [9]. They showed that vigilance problems occur quite rarely but are generally sufficient by themselves to degrade the driving situation, while in most cases an attentional problem requires the contribution of others factors to worsen the situation.

Another divergence between the authors concerns the concept of distraction and whether or not "purely" cognitive distractions ("being lost in one's thoughts") are included in the definition. Authors often consider that a secondary activity is necessary to talk about distractions, that is to say that a triggering element is needed. Here, we will rely on the classification by Van Elslande et al. [9], which distinguishes attention problems according to the task (divided attention problem) or the distracter (selective attention problem) that interferes with the critical driving activity. The advantage of such a classification is that it provides a differentiation between attention difficulties which are directly linked to the driving task and those which refer to secondary activities. Such a distinction is considered crucial, notably from an ergonomics perspective. In fact, for operational purposes, looking in the mirror to check the feasibility of a manoeuvre or gazing at a helicopter, for example, cannot be viewed as the same kind of "distracting activity". Three categories of attention disturbances are defined:

- 'Inattention', resulting from interference between a driving task and personal concerns, to the detriment of the former;
- 'Attention competition', resulting from interference between several tasks relevant to driving (e.g. guiding a vehicle and following an itinerary), to the detriment of one of them;

- 'Distraction', resulting from interference between a driving task and an external stimulation not linked to driving (e.g. guiding a vehicle and tuning the radio). This secondary task can be gestural or visuo-cognitive.

The aim of this study, based on an in-depth analysis of accidents, is to identify the type of driving errors induced by each of these attention disturbances: Are there differences in the impairment of driving functions according to the attention disturbance? Secondly, we evaluate the level of influence of attention disturbances in the emergence of driving errors. Indeed, the mere presence of attention problems is not always a sufficient condition to cause a failure. As in any complex event, the deterioration of the situation is often brought about by a combination of several elements, attentional and others. It is therefore essential not to limit the analysis to the sole identification of an attentional disturbance, but also to establish its effective role in the genesis of the accident.

2 METHOD

In order to investigate attentional problems, we relied on data taken from the in-depth accident studies (EDAs) performed at INRETS-MA, putting the emphasis on the cognitive mechanisms involved. The advantage of working on accidents lies in focusing the research on human errors that pose a real safety problem, without lingering on the everyday mistakes that have no consequences on safety. Data are collected by multidisciplinary teams consisting of a psychologist whose role involves interviewing drivers about the circumstances of the accidents, and a technician specialized in infrastructure and vehicles, whose mission is to record the material traces and to diagnose the physical conditions of the accidents. The advantage of this method lies in its systemic approach, taking into account the three components of the road system: human, vehicle and infrastructure, and more importantly their interactions. Compared to police reports, EDAs offer a far more precise data collection,

notably making it possible to emphasize the drivers' errors as well as the factors that cause these errors.

Different models of human errors can be found in the literature, some of them being particular to driving activity (e.g. [10], [11], [12]). We will base our analysis on the HFF (Human Functional Failures) model [12] for its operational aspects and the clear differentiation that it gives between human error (of detection, etc) and human factors (such as alertness or inattention) of this error. Human error is discussed here in terms of functional failure which characterizes the momentary inability of a human function (sensory, cognitive or motor) to handle a difficulty, which leads to a breakdown in managing the situation. There are six categories of human functional failures. The first five correspond to the different stages of information processing: detection, diagnosis, prognosis, decision and execution. The last one is an alteration of the functional chain in its entirety, called 'overall failure'. These six categories give rise to 20 types of specific functional failures.

- Detection failure: Explains accidents directly attributable to the non-detection of certain key parameters of the situation
 - Detect1: failure to detect in visibility constraints (e.g. an animal at night)
 - Detect2: focalized acquisition of information (e.g. on vehicle considered as a source of danger)
 - Detect3: hasty search for information (e.g. cursory look when making a left turn)
 - Detect4: interruption in information acquisition (looking outside the road scene)
 - Detect5: failure to recognize information acquisition demands (e.g. late detection of the vehicle ahead slowing down while being lost in one's thoughts)

- Diagnosis failure: Failure to estimate physical parameters and understand situations
 - Diag1: incorrect evaluation of a road difficulty (e.g. underestimating the magnitude of an unknown bend)
 - Diag2: incorrect evaluation of a gap (e.g. the possibility to cross)
 - Diag3: incorrect understanding of how the site functions (e.g. misunderstanding of a crossroad functioning)
 - Diag4: incorrect understanding of a maneuver undertaken by another user (e.g. due to lack of indicators)

- Prognosis failure: Problems related to processes of anticipation and prediction
 - Prog1: not expecting a maneuver by another user (e.g. the starting up of a vehicle without right of way)
 - Prog2: expecting adjustment by another user (e.g. that the opposite driver will stop)
 - Prog3: expecting no disturbance ahead (e.g. in a bend without visibility)

- Decision failure: Failure in the choice of driving strategies
 - Dec1: directed violation (e.g. linked to a visual disturbance that forces the driver to move forward on the road)
 - Dec2: deliberate violation (e.g. a driver who decides not to stop at a stop sign)
 - Dec3: violation error (a violation triggered by automatism)

- Execution failure: Includes accidents where a vehicle control problem arises
 - Exec1: vehicle controllability (e.g. due to gusts of wind, heavy rain, etc)
 - Exec2: guidance defect (e.g. interruption of guidance after a drop in attention)

- Overall (or general) failure: Impairment of the entire functional chain of conduct

- Gen1: loss of psychophysiological ability (due to fainting or falling asleep)
- Gen2: impairment of sensorimotor and cognitive abilities (due to drug or alcohol abuse)
- Gen3: exceeding cognitive abilities (e.g. aberrant manoeuvres such as taking the motorway against the flow of traffic)

Moreover, this methodology allows us to highlight the explanatory elements at the origin of these functional failures, that is to say: the factors of error, combining human factors and others. Generally, none of these factors by itself can explain the emergence of a failure. They usually combine with each other. These elements can be endogenous (directly related to driver's status and internal conditions for achieving the task) or exogenous (related to the infrastructure, vehicle or environment). Certain endogenous elements concern the driver's attention. Eight elements of attention disturbances have therefore been defined from in-depth accident data [13] and distributed depending on the specific type of attention problem that they generate: inattention, attention competition or distraction (Table 1).

Table 1: Explanatory elements related to attentional disturbances

Types of attentional disturbances	Explanatory elements derived from EDA
Inattention	<ul style="list-style-type: none"> - Low level of attention (e.g. leisure journey) - Thoughts, concerns - Over-familiarity with the road/monotony - Over-familiarity with the maneuver
Attention competition	<ul style="list-style-type: none"> - Searching for a direction - Identification of a potential risk in another part

	of the situation (e.g. a car coming from the other side)
Distraction	- External stimulus (phone, conversation with a passenger, etc.) - Secondary task (tuning the radio, picking up an object, etc.)

In order to clarify the role of attentional disturbances in the genesis of driving errors, the degree of impact of the corresponding explanatory elements was estimated using three levels:

- Impact 1: the element has a major, 'decisive', influence on the production of a driving error. The suppression of this element would have sufficed to avoid the problem: if the functional disturbance had not occurred, the accident would not have happened.
- Impact 2: an intermediate level which reflects a participatory, 'co-decisive', influence of attentional explanatory elements with the contribution of other kinds of factors in the production of the human functional failure.
- Impact 3: the elements do not have a strong influence on the onset of the functional failure; their influence is only 'contributory'. They promote the malfunction, but in their absence, the human functional failure would have occurred anyway due to the weight of all the other factors involved.

The sample studied consists of 389 drivers involved in traffic accidents, these drivers having at least one attentional explanatory element contributing to their functional failures. As we can see below, inattention is the attentional disturbance that has the highest occurrence rate (74%) in accident apparition, compared with attention competition (18%) and distraction (8%). Only drivers who had one particular attentional problem are included in our sample.

3 RESULTS

In half the cases, attention disturbances led to a detection failure (table 2) and most attentional elements required variables of other kinds as they had a co-decisive impact in 56.6% of the cases and a contributory influence in 29.3% (table 3). However, if we look at each attention problem, we can see differences in the driving failures they generate and in terms of the impact of the factors involved.

Table 2: Overall distribution of failures linked to attentional disturbances (n=389)

detection	diagnosis	prognosis	decision	execution	overall
44.7%	18.8%	16.5%	8.8%	9.5%	1.8%

Table 3: Levels of impact of attentional elements on human failure production (n=389)

impact 1	impact 2	impact 3
14.1%	56.6%	29.3%

3.1 Inattention

Inattention is the attentional disturbance most frequently represented (74%, all impact levels combined). In 38.5% of cases, a problem of inattention led to detection failures, in 21.9% to diagnosis failures and in 21.2% to prognosis failures (figure1). Among these categories of failures, four specific types stand out the most:

- Detect1: failure to detect linked to a lack of visibility (11.1%): These drivers are suddenly confronted with a changing situation, often linked to encountering an interaction with another user not detected early enough to implement appropriate strategies.

- Detect3: hasty search for information (16.6%): This failure refers to a defective information-gathering procedure which does not detect an interfering vehicle.
- Detect5: failure to recognize information acquisition demands (12.5%): information seeking is very diffuse, linked to a minimization of the task requirements at a given time by the driver.
- Diag1: incorrect evaluation of a road difficulty (10.8%): Here, there are drivers who encounter difficulties with infrastructure, such as negotiating curves which require adjusting speed and trajectory.

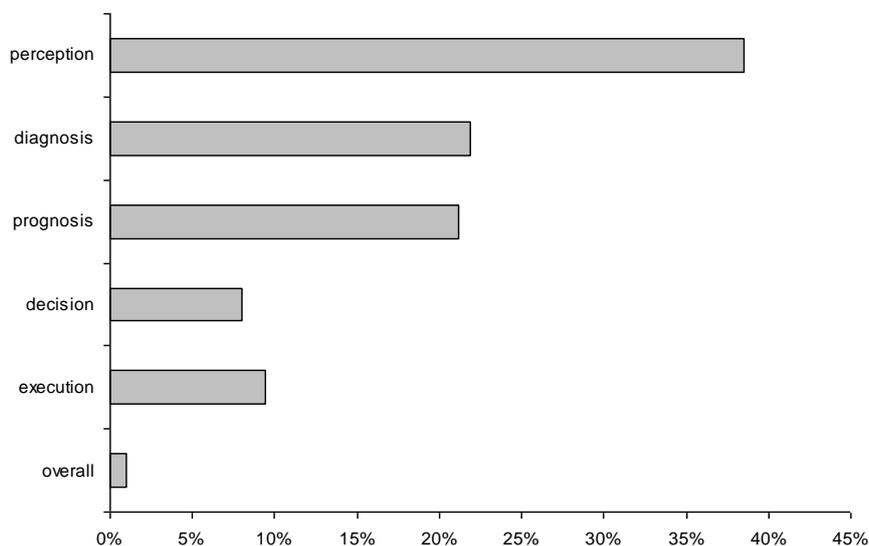


Figure 1: Distribution of drivers' functional failures linked to inattention (n=288)

Four elements cause problems of inattention, in different proportions and with a different impact (figure 2).

- Over-familiarity with the road/monotony: this element is by far the most represented in cases of inattention. Strong experience of travel is involved in 61.8% of those cases implying inattention. This element includes road users who drive in an automated way due to over-experience, such as on a routine short distance home-work or home-family trip.

- Low level of attention: this element is involved in 28.8% of accidents. This corresponds to a diffuse state of attention, for example on easy roads or leisure-type routes.
- Over-familiarity with the manoeuvre: co-explains 18.7% of accidents. Experienced with the journey, but with greater focus on a particularly well known manoeuvre, the driver performs his action in an automated way (e.g. a daily manoeuvre performed at the same intersection).
- Thoughts, concerns: this element is involved in 12.8% of accidents. The distraction comes from the driver, such as a thought that grabs his attention at the expense of driving.

The weight of inattention within the accident rate seems to be moderate, this factor having mainly a co-decisive impact (54.5%). Moreover, this is the failure that has the highest rate of only contributory influence (35.8%) (table 4). Therefore, in most cases, a problem of inattention in and of itself does not lead to the drivers' error. Other factors are necessary to impede the driving situation. Only one specific inattention element does not fulfil these conditions: driver's concerns. In 35.1% of cases, this factor has a decisive influence (figure 2).

Table 4: Levels of impact of inattention elements on human failure production (n=288)

impact 1	impact 2	impact 3
9.7%	54.5%	35.8%

Some endogenous or exogenous elements therefore co-explain the occurrence of failures (figure 2). We will only consider explanatory elements that are present in at least 10% of accidents.

- Priority feeling: this co-explains 23.9% of failures. The confidence generated by this priority status (notably at intersections) will indirectly play a part in the attention that the driver pays to the possible arrival of a non-priority user on his path.

- Speed: high speed co-explains 27% of failures. This element can disturb the conditions for regulating the situation and increase the negative effects of inattention problems.
- Lack of visibility: restricted visibility (road design, trees, buildings, etc.) and obstruction to visibility (other vehicles, sun, etc.) respectively co-explain 18.4% and 13.2% of failures.
- Atypical manoeuvre by another user: this co-explains 30.2% of failures. In addition to the failure of the driver, there is an interaction with another vehicle that intentionally or unintentionally violates a safety rule. An unusual manoeuvre by another driver is often indicative of a latent attention problem.

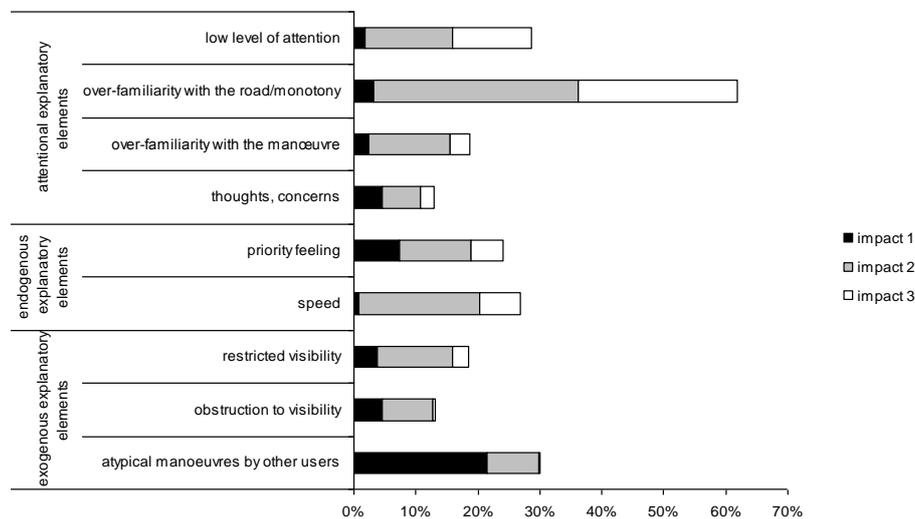


Figure 2: Distribution of explanatory elements and of their level of impact on drivers' failures (n=288)

We have shown that problems of inattention mainly lead to detection, diagnosis and prognosis failures. For each failure, the main attentional explanatory element is “over-familiarity with the road”. The difference tends to lie in the combination of these attentional elements with other variables of a different nature. When a problem of attention leads to detection failures, in 58.9% of cases there is the “lack of visibility” explanatory element, linked to infrastructure (buildings, vegetation, etc.) or a temporary lack of visibility (sun, truck, etc.). At the origin of

diagnosis failures, we find drivers who know the route very well but who drive a little too fast for the driving conditions such as curves or when overtaking. In the last case, knowledge of the route reinforces the drivers in their priority feelings. They do not anticipate any dangerous behaviour from other drivers, especially at intersections. This results in prognosis failures.

3.2 Attention competition

Attention competition represents 18% of the 389 accidents involving an attentional disturbance. It leads to a large majority of detection failures (figure 3). Only one type of failure differs significantly from the others:

- Detect2: focusing on part of the road scene (65.7%): this concerns the focus of the driver's attention on a partial aspect of the situation at the expense of others and is often the result of a particular difficulty encountered in the driving task.

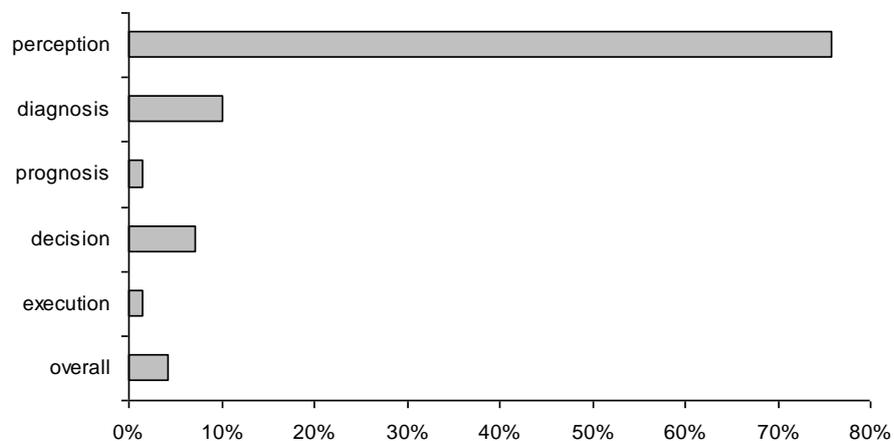


Figure 3: Distribution of drivers' functional failures linked to attention competition

(n=70)

Two elements are at the origin of attentional competition (figure 4). Drivers mobilize their attentional resources on an element identified as a source of risk or on their search for a direction, to the detriment of detecting an important element in the road scene.

- Searching for a direction: in 51.4% of cases, the driver, who is seeking a destination, directs his attention toward directional signs or to the edge of the carriageway looking for a road or property.
- Identification of a potential risk: in 48.6% of cases, the driver focuses on a source of danger he has identified, to the detriment of the rest of the scene. His attention is diverted toward another object and as a consequence cannot detect the potential accident situation.

Whether the source of attentional competition is “searching for a direction” or “identification of a danger”, the impact will be co-decisive in 70.4% of cases (table 5). Other elements will therefore co-explain this attentional competition problem (figure 4). Two scenarios can be defined, depending on the attentional element involved, as described below.

Table 5: Levels of impact of attention competition elements on human failure production (n=70)

impact 1	impact 2	impact 3
26.8%	70.4%	2.9%

When attention competition comes from a search for a direction, three others variables co-explain the most the emergence of failures:

- Site unfamiliarity: in all these cases, the drivers did not know the site or the route.
- Complexity of the site and equipment problems: these variables combine with “searching for a direction” in 22.2% and 25% of cases, respectively. This happens at complex intersections, for example, or when the road site is atypical, not legible or not adapted to certain vehicles.

When attention competition comes from the identification of a danger, two exogenous variables co-explain the emergence of failures:

- Difficulty in finding a gap to cross or to merge: in 26.5% of cases, the speed or density of traffic participates in the emergence of the failure.
- Atypical manoeuvre by another user: this variable is combined with the identification of a potential risk which captures attention in 32.4% of cases.

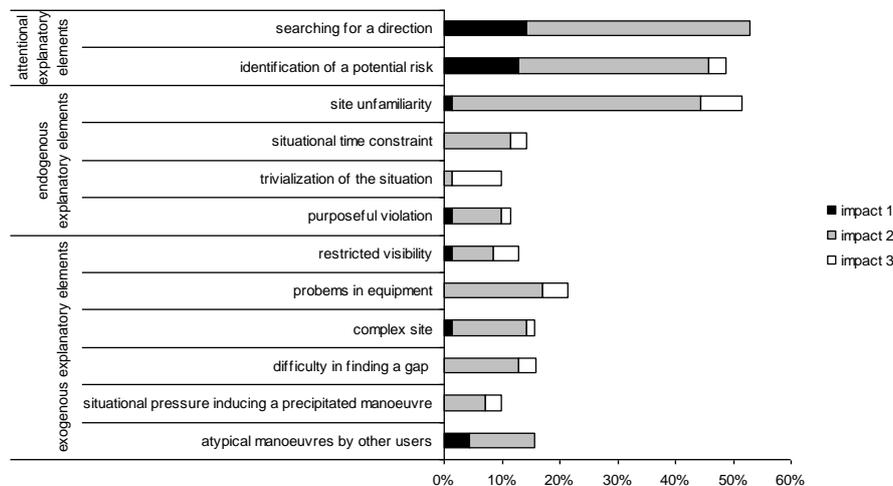


Figure 4: Distribution of explanatory elements and of their level of impact on drivers' failures (n=70)

3.3 Distraction

Distraction is poorly represented in the accident rate (8%). It mainly leads to detection failures (32.3%) and execution failures (29%) (figure 5). Two types of failures stand out:

- Detect4: Interruption of information gathering (12.9%): drivers momentarily interrupt the monitoring of their environment to accomplish another task (various activities unrelated to the driving task in progress: a discussion with a passenger, contemplation of the landscape, adjusting the radio). This secondary task mobilizes both their eyes and their attention.

- Exec2: problems of vehicle guidance (29%): here, there is no external constraint (such as wind, a puncture, etc.) that disrupts driving. The problem comes from the poor allocation of attentional resources to the control of the trajectory activity.

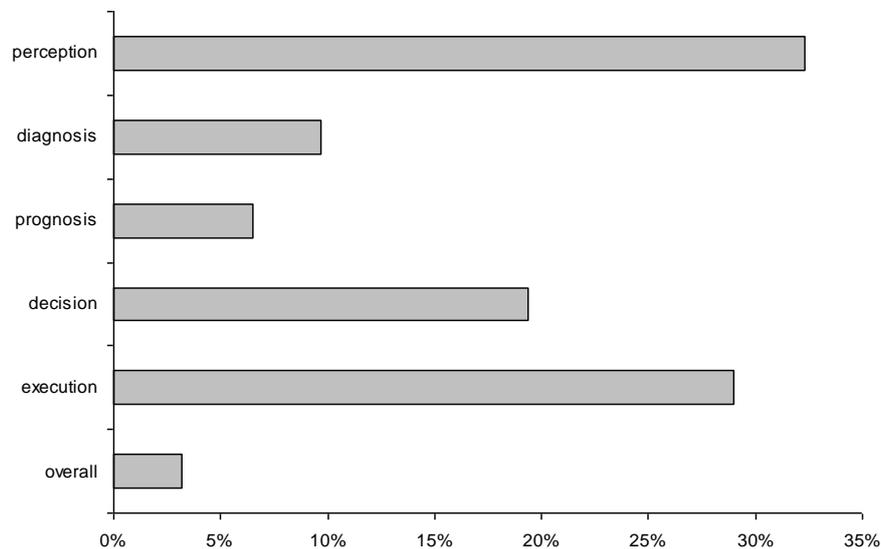


Figure 5: Distribution of drivers' functional failures linked to distraction (n=31)

Two attentional elements are at the origin of distraction:

- External stimulus: 67.7% of drivers who have a distraction problem divert their attention to a distracter such as a conversation with a passenger, their cell phone or listening to the radio, so that the quality of execution of the driving task becomes impaired.
- Secondary task: this element represents 32.3% of drivers with a distraction problem. The driver not only turns his attention but also his gaze toward an object external to the driving task (adjusting the radio, picking something up) and entirely mobilizes his resources to the execution of this activity unrelated to driving.

Distraction is the disturbance that has the strongest impact in the production of a failure (table 6). Its influence is decisive in 35.5% of cases and co-decisive in 48.4%. However, the two explanatory elements at the origin of the distraction do not have the same weight. In the case

of a 'materialized' additional task, the influence is decisive in 90% of cases, whereas for a cognitive distraction by an external element (telephone, children, etc.), the proportion is only 9.5%. Among other variables that combine with attentional explanatory elements, speed is the most represented (25.8%).

Table 6: Levels of impact of distraction elements on human failure production (n=31)

impact 1	impact 2	impact 3
35.5%	48.4%	16.1%

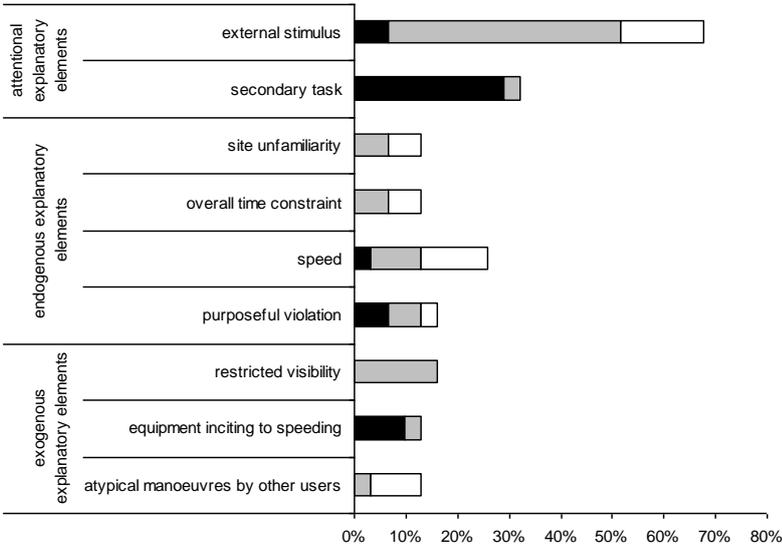


Figure 6: Distribution of explanatory elements and of their level of impact on drivers' failures (n=31)

4 DISCUSSION

This study gives rise to several conclusions. Firstly, we can observe that the different attentional disturbances are dissimilar on several points in terms of the errors they generate, the combination between elements – attentional and others – and the impact of these elements.

First of all, although these disturbances generate a majority of detection failures (74%), there is also a significant proportion of diagnosis and prognosis failures linked to inattention, and a high percentage of execution failures linked to distraction. Moreover, there are even differences within the detection failures. For a case of inattention, this essentially means taking information that is too succinct; for attention competition, the problem concerns focalized information seeking; and for distraction, information gathering on the road scene is interrupted.

Secondly, the explanatory elements combined with attentional elements leading to driving errors vary from one disturbance to another. There may be an endogenous element such as excessive speed or an exogenous element such as restricted visibility. However, although attentional disturbances mainly have a co-determinant impact, this is not identical for each of them. While inattention has the highest accident rate in which the attentional element only has a contributory influence, distraction has the greatest impact in the emergence of a failure, its influence being decisive in 35.5% of cases.

It is therefore necessary to take into account not only the presence of a factor, but also its weight in the appearance of the error. Indeed, distraction is a failure that occurs rarely but in one third of the cases where it does, it is sufficient in and of itself to lead to an accident. Conversely, in most cases, an inattention type of disturbance requires other factors to degrade the driving situation.

New technologies could be a way to solve some attentional problems, but they also have the potential of having the opposite effect of bringing about others. To promote the adaptation of these systems, we must establish exactly what the driver's needs are and define, as a consequence, the driving aids that are best suited to these needs. These needs correspond to something that has failed in the driving system, in defence and/or protection. Thus, crashes can be seen as the symptom of these lacks, and functional failures give a more precise indication of what the drivers lacked to compensate for the difficulties they encountered. The functional failures observed among drivers as diagnosed from in-depth accident analyses will therefore provide us with a more precise understanding of the needs associated with each attentional disturbance.

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