AGE, SKILL, AND HAZARD PERCEPTION IN DRIVING

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Key words

Hazard Perception, Risk Perception, Eye movements, Skill, Experience, Age, Memory, Schema, Mental Model, Driving Experience, Potential and Materialized hazards.
Abstract
The research examined age and skill effects on hazard perception while driving the road. 16 old-experienced (65 -75 years), 19 experienced (22-30) and 21 young-inexperienced (17-18) drivers observed six hazard perception movies and had to complete two tasks. Subjects were first instructed to press the button each time they recognize a hazard. During this part of the experiment subjects were connected to eye movement device. Results showed that young-inexperienced drivers were the least sensitive to respond to immaterialized hazards which occurred after the planned-in-advance events. When the hazard was imminent all drivers responded at the same time. Old-experienced drivers responded later than the other groups usually at intersections that did not include any imminent danger. Eye movements' analysis revealed that all drivers detected the elements in the environment when they were salient, but gazing towards the right side where a road emerges or towards parked cars on the right characterized only the more experienced drivers. The young-inexperienced drivers tended to look straight forward.

In the second part subjects observed the movies again and in the same order as in the first presentation. They were then requested to classify all movies into an arbitrary number of groups according to their similarity in their hazardous situations (Benda and Hoyos, 1983). Old-experienced drivers tended to classify the movies according to general environmental attributes whereas the majority of young-inexperienced drivers tended to relate more to the materialized events as the classification criterion.

The research suggests that experienced drivers may be regarded as those who prevent hazardous events while young-inexperienced drivers only respond to them. By responding to more hazardous events drivers learn to estimate the probability that a hazard will occur and to set the level of hazardousness in a situation according to subjective experience based on its outcomes. Therefore, experienced drivers are more sensitive to potential hazardous situations and can predict future events (Endsley, 1995).
Presenting hazard perception movies to young-inexperienced drivers in which they need to detect hazards might improve their ability to detect potential hazards and will hopefully reduce their accident involvement. In addition, old-experienced drivers who were upset when other drivers didn’t indicate their intentions are dependent on such signs and therefore increasing the awareness regarding this issue is important.
Table of Content

1 Introduction ........................................................................................................... 1

  1.1 Car crashes ...................................................................................................... 1
    1.1.1 Casualties in Driving-Related Crashes ..................................................... 1

1.2 Traffic environment .......................................................................................... 1
    1.2.1 Traffic environment is complex and dynamic ........................................... 1
    1.2.2 Driver performance in complex and dynamic environment ...................... 2

1.3 Driving skill: Hazard perception ....................................................................... 4
    1.3.1 Definitions .................................................................................................. 4
      1.3.1.1 Hazard ................................................................................................ 4
      1.3.1.2 Hazard perception .............................................................................. 5
    1.3.2 Hazard perception: process and mental structures .................................... 5

1.4 The effects of age and experience on hazard perception ................................. 6
    1.4.1 Experience improves hazard perception .................................................. 6
    1.4.2 Practice improves cognitive structures and hazard perception ................... 7
    1.4.3 Hazard Perception-Situation Awareness for dangerous situations- and
ewhazard and risk perception in old drivers ...................................................... 12

2 Hypotheses .......................................................................................................... 14

3 Method ............................................................................................................... 15

  3.1 Subjects ......................................................................................................... 15
  3.2 Apparatus ....................................................................................................... 15
  3.3 Procedure ...................................................................................................... 16
  3.4 Hazard perception movies scripts .................................................................. 19
    3.4.1 Movie 1 ................................................................................................... 19
    3.4.2 Movie 2 ................................................................................................... 20
    3.4.3 Movie 3 ................................................................................................... 21
    3.4.4 Movie 4 ................................................................................................... 21
    3.4.5 Movie 5 ................................................................................................... 22
    3.4.6 Movie 6 ................................................................................................... 23

4 Results ............................................................................................................. 24

  4.1 Hazardous situations sensitivity and response .............................................. 24
    4.1.1 Event attitude - general description ....................................................... 24
    4.1.2 Defining events ....................................................................................... 24
    4.1.3 Event importance - support and confidence ........................................... 25
4.1.4 Between movies – Non-event analysis ................................................. 26
4.1.5 Movies event analysis ................................................................. 27
   4.1.5.1 Movie 1 events analysis ....................................................... 31
   4.1.5.2 Movie 2 events analysis ....................................................... 34
   4.1.5.3 Movie 3 events analysis ....................................................... 36
   4.1.5.4 Movie 4 events analysis ....................................................... 41
   4.1.5.5 Movie 5 events analysis ....................................................... 44
   4.1.5.6 Movie 6 events analysis ....................................................... 47
4.1.6 Before/After-planned-in-advance-events’ analysis .................................. 49
4.1.7 Intersections response sensitivity ...................................................... 51
   4.1.7.1 Vehicle crossing an intersection in the control movies .................. 53
4.2 Subject’s movies classification .......................................................... 55
   4.2.1 Between and within drivers type classification .................................. 57
      4.2.1.1 Hazard type classification ............................................... 62
      4.2.1.2 Traffic environment characteristics classification ..................... 63
4.3 Subjects’ titles for classified movies subsets ......................................... 65
5 Discussion ......................................................................................... 69
   5.1 Performance on the specific dependent measures .................................. 69
      5.1.1 Subjects button presses: reactions to hazards .............................. 69
         5.1.1.1 General events analysis ................................................... 70
         5.1.1.2 Specific events’ analysis ................................................... 71
      5.1.2 Eye movement analysis ......................................................... 73
         5.1.2.1 General eye movements' analysis ....................................... 74
         5.1.2.2 Events specific eye movements' analysis .............................. 74
   5.2 Movies classification and titles ....................................................... 76
   5.3 Conclusions and summary ............................................................ 79
   5.4 Research limitations and future research ......................................... 79
6 References ....................................................................................... 81
7 Appendix.......................................................................................... 85
List of Tables
Table 4.1.2.1. Planned-in-advance and unplanned-in-advance events ......................... 25
Table 4.1.5.1. Groups comparison encoding ................................................................. 30
Table 4.1.7.1. Responds to intersections events ............................................................ 52
Table 4.1.7.1.1. Vehicle crossing the intersection analysis .............................................. 53
Table 4.2.1. Movies categories .................................................................................. 55
Table 4.2.1.1. Number of observations, Support, and Confidence for each group........ 60
Table 4.2.1.2. $X^2$ analysis' summary according to most meaningful movie groups. ..... 61
Table 4.3.1 Titles for movies group 1-5 ..................................................................... 67
Table 5.1.1.2.1: Reaction time, Response sensitivity and Classification type analysis. 71
Table 5.1.2.2 Eye movements' results summary ......................................................... 74

List of Figures
Figure 3.3.1. Second part experimental procedure ....................................................... 17
Figure 4.1.5.1. Events analysis classification algorithm ............................................... 27
Figure 4.1.5.1.3.1. Drivers’ reaction time to the braking car episode ......................... 33
Figure 4.1.5.3.4.1. Fixations on frames 360, 380 and 400 ............................................. 38
Figure 4.1.5.3.4.2. All fixations from frames 605-630 superimposed on frame 605 ...... 40
Figure 4.1.5.4.4.1. Frames 500 and 525 with and without fixations superimposed. ..... 43
Figure 4.1.5.5.3.1. All fixations on frames 160-178 superimposed on frame 170 ....... 46
Figure 4.1.5.6.3.1. AFN and ARL for all drivers' groups in event 6_1 ....................... 48
Figure 4.1.6.1. Percent of events responded to before/after planned-in-advance events 50
Figure 4.1.7.1. Response to intersection events according to their type .................... 52
Figure 4.2.1.1. Movies classification pictures .............................................................. 58
Figure 4.2.1.2. Common movies groups' classification ............................................... 59
1 Introduction

1.1 Car crashes

1.1.1 Casualties in Driving-Related Crashes

Driving safety had always been an important issue worldwide. In the last decade, technology made enormous progress and enabled designing much safer vehicles. However, car crashes are still very high – the number one cause of mortality in the age group of 5-35 in the Western world. In the united state alone, 42,815 people were killed and 2,926,000 were injured in 2002 as a result of traffic crashes (U.S department of transportation, 2002). The economic cost of traffic crashes in 2000 was estimated in an enormous amount of $230.6 Billions. The reasons for a crash are diverse. Understanding the causes of a crash will allow finding ways in which crashes can be reduced, save the lives of thousands and save lots of money.

Sabey and Staughton (1975) claimed that the causes of car crashes can be divided into three types: behavioral, vehicular and environmental, with the behavioral being the most important. Various studies have estimated the contribution of driver error at approximately 90% (Treat et al., 1975; Sabey and Staughton, 1975; Lewin, 1982) and even as much as 99% (NHTSA, 1999). Elander, West & French (1993) say that it is a great challenge for psychology to provide a better understanding of the role of human factors in the causation of road-traffic crashes. In order to understand the role of human factors in road-traffic crashes it is most appropriate to begin in describing the traffic environment and the abilities of humans to cope with it.

1.2 Traffic environment

1.2.1 Traffic environment is complex and dynamic

Driving is a demanding task combining complex motor and cognitive skills. A typical driving task during the day may include maneuvering among other vehicles, paying attention to other road users (drivers and pedestrians), and discerning road signs and obstacles (both static and dynamic). The total amount and rate of information that is presented to the driver is typically "much more than a human brain can handle at a given time either at the amount of information or its complexity. This complexity creates huge individual differences in visual perceptual world" (Chun, 2003). Endsley (1995) mentions that in dynamic environments, decisions must be made under severe time constraints and tasks are dependent on an ongoing up-to-date analysis of the environment. Hughes and Cole (1986) stated that the road environment presents a vast array of visually accessible information but drivers notice and attend to only small
fraction of the total available information. In a study conducted by Benda and Hoyos (1983) all subject agreed that "permanently changing speed and the quickly changing situations in daily traffic, where the large information flow per time unit requires high perceptive and cognitive selectivity and constant vigilance, constitute a group of driving conditions with a high hazard potential".

1.2.2 Driver performance in complex and dynamic environment

Chun (2003) claims that information overload leads to dramatic gaps in people's perceptual grasp of the world and that humans have developed sophisticated attentional mechanisms that help to overcome the overload of information within a visual scene. "Operators of complex and dynamic systems must understand the integrated meaning of what they perceive in light of their goals. Understanding the environment as a whole will form the basis for decision making (Endsley, 1995)". This holistic perception of the environment is often labeled as "situation awareness" (SA).

Endsley (1995) defines three hierarchical levels of information processing in order to achieve SA. The first level is the basic one and includes the perception of the elements in the environment (e.g. sounds, textures and objects). At the second level elements are put together to create coherent concept of the current situation. Endsley also notes that this is a critical phase where novice drivers experience difficulties in integrating the elements to create holistic understanding of the environment. The third and highest level includes the projection of the current situation to the immediate and near future. As previously mentioned, the second level of SA is crucial since it includes the integration of elements to create holistic understanding of the environment. The integration of elements is based on long term memory structures known as schemata. This structure is an efficient way to overcome the overload of information in the environment. Although in this process many of the details of the situation are lost, the information becomes more coherent and organized for storage (Endsley, 1995). With experience, schema becomes more abstract. According to Hintzman (1986), a schema is a temporary, dynamic structure that summarizes information in the memory traces activated by a cue. The schema fills uncertain details, and dictates expectancies. The more memory traces a driver has, the more abstract the schema. Thus, a single schema may serve to organize several sets of information. In the absence of schemata most of a person's active processing of information must occur in working memory, which is much slower and more demanding of cognitive resources. Indeed there is research showing that novice drivers fail to have a holistic understanding of the current situation (Benda and Hoyos, 1983; Brown and Groeger, 1988; Armsby, Boyle and Wright, 1989).
Eye movement research shows that novice drivers tend to fixate their gaze much closer to their car than experienced drivers (Mourant and Rockwell, 1972) and other research showed that novice drivers tend to concentrate more on static objects in the road system (Soliday and Allen, 1972). Crundell and Underwood (1998) found that the visual scanning patterns of experienced drivers appeared to adapt themselves to different road situations, while novice drivers tended to use the same scanning patterns for all road types. Also, novice drivers fixated for longer durations than experienced drivers. Longer fixations durations can indicate that it requires longer time to extract the meaning of elements in the environment and less eye movements might indicate their lower tendency on well-learned predetermined schema that dictates expectations. Vicente and Wang (1998) presented the constraint attunement theory in which the skilled operator is directed by constraints dictated by the environment. Therefore this operator can retrieve a solution from relatively small number of possible options. The inexperienced operator on the other hand is not familiar with any such constrains and therefore, as mention by Endsley (1995), is a helpless seeker of information within the environment. These results and research indicate that novice drivers do not use a specific schema and are not familiar with any environmental constrains. They also indicate that with the same level of mental effort experienced drivers extract more significant cues from the environment, aiding Long-Term-Memory to create a better understanding of the environment.

While experience is a major factor for better performance within traffic environment, individual differences also play a key role in driver's performance. According to Endsley (1995) "in complex and dynamic environments, attention demands resulting from information overload, complex decision making and multiple tasks can quickly exceeds a person's limited attention capacity". Elander et al (1993) presented research showing that the ability to detect visual targets embedded in a complex background and ability to switch attention rapidly appear to be associated with lower crash risk.

All measures mentioned so far were limited to driving skills. It is important to mention that there are driving style measures which include the choice of driving speed, threshold for overtaking, headway and propensity to commit traffic violations that might also contribute to traffic-crashes involvement (Elander et al 1993). This work will concentrate on hazard perception which is a part of driving skill measures. Horswill and Mckenna (2004) claim that from all different components of driving skill, only hazard perception has been found to relate to traffic-accidents across a number of studies (e.g.
Peltz and Krupat, 1974; Watts and Quimby, 1979; Mckenna and Crick, 1991). For example, Spicer (1964) showed participants number of traffic situations and after each traffic situation they selected items from a checklist which considered being important. Young accident-involved drivers performed worse in detecting essential features from the environment than accident-free drivers. Furthermore, Pelz and Krupat (1974) asked participants to move a handle while observing traffic films. They had to detect six hazards within those films. The point in which subjects began to move the handle was considered the time in which the hazard was detected. Drivers with no history of accidents or traffic offences detected the hazard 500 milliseconds before drivers with accidents record but no convictions, and 1200 milliseconds before drivers with accidents record and traffic convictions. Therefore, in order to reduce traffic-crashes it is necessary to understand hazard perception skill, what factors within hazard perception contributes for better performance and which factors are improvable.

1.3 Driving skill: Hazard perception

Since hazard perception considered a driving skill it is important to define skill. According to Logan (1985) "skill is a term usually applied to performance of a complex task". The task itself is considered a skill, and those who perform better on it are considered more skilled than those who perform worse. A task is a set of goals which a person is trying to obtain and a set of constraints to which the person must adapt in order to obtain the goals". Those constraints includes rules which are part of the task environment and some are part of the performer such as limits on working memory, limits on task-relevant knowledge or even strength and agility. Importantly, a skill could be acquired through practice. Awareness to environmental constrains- as mentioned by Vicente and Wang (1998) - are highly important for better performance. Thus, finding those differences between inexperienced and experienced drivers in their ability to detect hazards, understand the current situation and predict near future events will help to understand inexperienced drivers limitations and finding ways by which to improve their hazard perception skill without risking unnecessary lives.

1.3.1 Definitions

1.3.1.1 Hazard

According to literature, there are many definitions for hazard. Haworth, Symmons and Kowadlo (2000) concluded, "in terms of hazards to road users, any object, situation, occurrence or combination of these that introduce the possibility of the individual road user experiencing harm should be included. Hazards may be obstructions in the roadway, a slippery road surface, merging traffic, weather conditions, distractions, a
defective vehicle, or any number of other circumstances." Benda and Hoyos (1983) claimed that occasionally people confound hazard with acceptance of risk. For example, two drivers can identify dangerous situation but only one might change his behavior in time to avoid the situation. The level of risk by which drivers evaluate situations varies across drivers (Finn and Bragg, 1986; Matthews and Moran, 1986). However, comparing level of risk acceptance might only be compared between drivers with same level of skill. If, for example, a young-inexperienced drivers observe an element or an object and he or she lacks the knowledge base of what this object might do he or she may not relate to it as dangerous. On the other hand an experienced driver who experienced similar situations in which this object was dangerous then he or she might change is behavior accordingly.

1.3.1.2 Hazard perception

According to Mills, Hall, McDonald and Rolls (1988) hazard perception might be considered as the ability to read the road. Crick and Mckenna (1991) stated that hazard perception is the ability to identify potentially dangerous traffic situations. Horswill and Mckenna (2004) relate hazard perception to Endsley's (1995) concept of situation awareness, by saying that hazard perception can be considered as situation awareness for dangerous situations in the traffic environment. These definitions suggest that hazard perception improves with practice. Therefore, it is important to understand processes and structures, which help acquiring hazard perception, how they are affected by skill and age.

1.3.2 Hazard perception: process and mental structures

Hazard perception was defined by Horswill and Mckenna (2004) as: situation awareness for dangerous situations. According to Endsley (1995) "people are not helpless recipients of data from the environment but are active seekers of data in light of their goals". Searching for dangerous situations activates a mental model (complex schemata in long-term memory that is used to model the behavior of a system) which direct attention to critical elements in the environment to achieve situation awareness, and enables drivers to predict future dangerous events. Simultaneously with this top-down process bottom up processing will occur. Patterns in the environment- that are recognized by the driver and do not fit the active mental model- might change his or her goals and revised the mental model (Endsley, 1995). She also mentioned that the alternating of top-down and bottom-up processing allows a driver to process information effectively in the traffic environment. As previously mentioned, working memory is important since it allows drivers to process and integrate information, which
he or she receives from the environment. Better working memory capabilities (with same practice level) will allow faster processing and can lead to a faster understanding of the environment and identifications of hazardous situations. Also divided attention capabilities were mentioned earlier as factors that can reduce road crashes. A driver with better dividing attention capabilities can process more elements in parallel and therefore can be ready for unexpected events, which might occur.

Traffic-crashes data showed that inexperienced drivers are more involved in crashes than experienced drivers. According to Horswill and McKenna (2004) like any skill, it is reasonable to assume that drivers become better in the ability to detect hazards as their experience grows. They presented research showing that novices are slower in detecting hazards and they often recognize smaller numbers of hazards than experienced drivers. They add that experience is likely to be a key influence on hazard perception independent of age (Age has different effects that will be discussed later).

According to Endsley’s (1995) SA model, actions are chosen from long term memory as scripts if such exists and are based on working memory if they aren’t. The operator actions affect the environment and as a result it affect his or hers perception. Smeets and Brenner (2001) claim, that perception and action are inseparable. They claim that one cannot study perception separately from action. These researches present a definition for action taken from Michaels (2000): “a temporally bounded, observable, goal-directed movement (or non movement) that entails intention, the detection of information, and a lawful relation between that information and the movement.” These researchers suggest that all actions are eventually a result of our perception. In the context of hazard perception, it seems that actions contribute meaningfully to the ability to perceive hazards.

1.4 The effects of age and experience on hazard perception

1.4.1 Experience improves hazard perception

Practice makes perfect. Hazard perception is a skill which gets better with practice and, therefore it is relatively improves but it never ends. Logan (1985) said that skill is relative rather than absolute and there is no maximum level of skill that can be attained. There can always be someone who is more skilled than the other. Thus, when talking about experience and its contribution to the ability to detect hazards it must relate to cognitive structures and process that improves with practice.
1.4.2 Practice improves cognitive structures and hazard perception.

A mental model, which represents a complex schema describing the environment, becomes more abstracted with experience. A well developed mental model can dictate expectations relative to the driver's goals and directs attention to critical cues in the environment that later will be integrated to create holistic understanding of the situation. Potential hazards must be detected by the driver, as soon as possible, in order to respond quickly and correctly. According to Endsley (1995) concept during level three in SA, a mental model will help the driver to predict where potential hazards might occur. Then patterns from the environment are matched to the present mental model (e.g. did the hazard appeared where it should?) and if it did not or something unexpected occurred the driver will consider a revision in the mental model or his or her goals. With the absent of proper mental model novices lack the ability to predict potential hazards and may detect them too late. Indeed, Brown (1982) found that novice drivers and experienced drivers differ in the ability to detect far hazards but there was no difference in near hazards. In a research conducted by Benda and Hoyos (1983) subjects were told to classify 39 normal traffic situations that showed different road and weather conditions into an arbitrary number of groups of similarly hazardous situations. Results showed that experienced drivers built up a rank order of groups dealing with hazardousness as quantity ("This is most… least hazardous group" etc.), while drivers with half experience than the former group classified the situations to a nominal scale, into groups of equal quality of hazardousness ("The situations in this group are similarly hazardous because of the intersections in each", "all wet road situations", etc). The researchers concluded that "the greater the driving experience the more able the driver to regard hazardousness as being a holistic attribute of the traffic situation and to integrate many different aspects of the situation". Less experienced drivers pay more attention to details and are less capable of integrating elements to a holistic representation of the hazardous situation. Schacter (1996) presented elegantly the power of forgetting. He mentioned that the ability to create abstraction depends on the ability to remember only important elements and neglect those that aren't. He also explained that people who remember too many details might be more susceptible to create abstraction. Furthermore, Hintzman (1986) claimed that a cue within the environment rises all past memory traces while all those common details from all memory traces construct the schema and all unique details are inhibited. That means that the schema contains only common details from all memory traces retrieved by the cue. In the previous context, this might explain why young-inexperienced drivers related to details.
Inexperienced drivers lack a knowledge base (Logan, 1985) and probably don’t have enough memory traces to create an appropriate schema. Those novices who lack experience give similar weight to irrelevant details (less common) and important details (more common). This explanation suggests that important elements within the traffic environment are common details that appear in the majority of past episodes rather than less frequent events that accidentally appeared in some of those pictures.

Endsley (1995) emphasizes level two in SA as a most influential factor that differentiates novices and experienced drivers. With the lack of the ability to integrate elements (understand the constraints according to the stimulus), it is impossible to predict hazards that might occur. A related issue is a growth in declarative knowledge with experience. Logan (1985) claimed that skilled performers usually know more about their capabilities and their strategic options than do unskilled performers. Endsley (1995) mentioned that general information about the system (i.e. default information) might allow people to operate effectively based on often, limited information. Experienced drivers have larger default information than novices and therefore they might predict or notice hazards, which might be missed by novices. For example, in an experiment made by Armsby et al (1989) old and young drivers had to rate pictures of different traffic situations as most or less hazardous. From a long list of situations (e.g. car overtaking, pedestrians, wet road, brow of hill, narrow road, etc) only fog was found to be significantly different between young and old drivers. Young drivers rated fog situation less hazardous than the older drivers did. It appears that in situations where danger is not explicitly seen the experienced drivers base their assessment on knowledge from the past which inexperienced drivers do not posses. These experienced drivers probably respond or acted back in their past when a car, for example surprised them from the fog. Finn and Bragg (1986) found that young drivers rated tailgating less hazardous than older drivers and in contrast they rated sudden emergence of a pedestrian in front of the driver more hazardous than older drivers. They explained that young drivers consider tailgating as a skill and therefore they are confident that they will be able to take action when it will be necessary, while pedestrian sudden emergence is unexpected danger and can cause to lack of control and therefore it is a dangerous situation. Another way to observe these results is by comparing these results with those of Armsby et al (1989). Young-inexperienced drivers probably lack the knowledge base of what might happen when tailgating. These drivers barely experienced a sudden brake by a leading car. The experienced drivers on the other hand are more afraid from the possible danger that didn’t actually occur. Tailgating might jeopardize them if they
don’t pay attention and expect a sudden brake whereas a pedestrian is no longer a threat after he or she was recognized.

It seems that the experienced driver is more afraid from the potential danger rather than the action he or she takes once the hazard is detected. According to Bragg and Finn (1986) older drivers rated pedestrians scenes less dangerous because they frequently meet these kind of events and usually these unexpected actions (i.e. pedestrians jump in front of the car) do not result in an accident. Apparently experience contribute to the improvement of the mental model that helps drivers to predict future potential hazards and to search, efficiently, for critical cues that will be integrated into a holistic understanding of the situation (i.e. to reach SA). Experienced drivers are ready and alert for potential hazards to come, but when hazard is detected they are less stressful than inexperienced drivers, they use their knowledge from the past to evaluate present situations and, hopefully, act properly in order to decrease the probability of a crash. Lack of knowledge and experience, causes stress when inexperienced drivers realize that they are in a dangerous situation. They are surprised because they did not expect the danger. It also leads to ignoring or misinterpreting danger in situations where no explicit hazard has been observed. Inexperienced drivers are helpless seekers of information, they posses impoverish mental model and they may allocate attention to unimportant elements in the environment. These drivers may observe a potentially dangerous situation without understanding that is in fact dangerous.

As any skill and expertise, hazard perception in traffic environment is specific, merely to this domain. Armsby et al (1989) reported that older drivers were less willing to rate task as less or more hazardous without being told the maneuver they should imagine themselves, to a greater degree than young drivers. Furthermore, these researches reported that subjects could not talk generally about road hazards and appeared to rely substantially on visual imagery with a tendency towards instantiations. Vicente and Wang (1998) suggests that skilled operator acts according to constrains within the environment. Therefore, the experienced driver who is familiar with constrains dictated by the schema must know in which environment he or she must act and what is their task. Unless they are familiar with the environment and its' constrains they are similar to the inexperienced operator. The inexperienced driver is by default less familiar with the environment and its' constrains and therefore for him or her additional information is useless. Vicente and Wang (1998) also demonstrated that since experienced operators are familiar with the environment constraints they might recall more details after performing the task. Underwood et al (2005) showed that experienced
drivers remembered more details from the environment. When a hazardous situation occurred the experienced drivers recalled more accidental events from the periphery, implying that their useful field of view is larger than that novice own.

In order to understand all environment constrains experienced drivers depend on their schema. The schema according to Hintzman (1986) is activated by a retrieval cue and therefore the experienced drivers had to know what they should do in order to activate their schema. There is a debate on whether hazard perception skill becomes automatic with practice. Automatic process is effortless and does not consume cognitive resources. Therefore, one might think that experienced drivers are in less effort when searching for hazards.

1.4.3 Hazard Perception-Situation Awareness for dangerous situations- and automaticity

According to Endsley (1995), acquiring situation awareness is different from the term SA that relate to a state of knowledge. Specifically, hazard perception can be considered as a state of knowledge (i.e. the driver understands that he or she is in danger or that the near future situation is hazardous, which means he or she is aware to the hazardous situation). But the maintenance of hazard perception along time is a process that has to be constantly maintained in order to identify future potential hazards. Fitzgerald and Harrison (1999) stated that hazard perception is a skill with cognitive and behavioral aspects that include cognitive workload, automation and attention.

At first look there seems to be a conflict between cognitive workload and automation since automaticity does not consume cognitive resources. A common example used to describe driving and automation is the situation when a driver drives home back from work. The driver obeys traffic rules and pay attention to traffic signs, but when asked to recall his or her trip he or she fails to do so. According to Endsley (1995) low level of attention is enough to retrieve information from long term memory (a proper schema) that affect the driver response. Indeed, as long as anything unexpected occurs, the "automatic driver" can drive home safely in effortless manner relying on long-term memory information. The question is how quickly and correctly, this driver may respond to unexpected event that might occur? Endsley (1995) added that by being less responsive to the feedback from the environment the driver might fail to detect unexpected events. This example fits one of the most important attributes of automatic process. The stimuli must have direct consistent mapping onto a response (Shiffrin and Schneider, 1977). Using the example a driver that drives the same way each day eventually develops a proper schema that allows him or her to drive home
properly, as long as nothing unexpected occurs, with minimum level of attention and in
effortless manner. Haworth et al (2000) claimed, "By their nature hazards that require
some change in behavior of the driver may not occur often enough for their processing
to become automated". This might differentiate the previous example that when driving
the same way allowing the driver to assess the "real" low probability of hazards (he or
she simply drives the same road many times and rarely something happen). In dynamic
environment, the number of hazards is infinite. There might be similarity between
hazardous situations but they are never the same. With practice, more hazardous
situations are saved separately in long term memory and crate larger array of situations
creating a well developed mental model that helps the experienced driver to categorize
situations as hazardous fast, to predict future hazards and allocate attention efficiently.
Over reliance on the mental model (ignoring feedback from the environment) might
cause a low level of SA and can cause the experienced driver to miss critical hazards.
Wickens (2001) noted that it is a trap to assume that a skilled driver posses higher
hazard perception than the novice driver. When a driver relies too heavily on the
relatively automatic, resource free schemata and expectancies, to guide his or her search
and to interpret new information, he or she may fail to correctly interpret (or even
notice) the unexpected and surprising event. Therefore, a skilled driver must allocate
resources in order to guarantee adequate hazard perception. Horswill and Mckenna
(2004) concluded that the ability to detect hazards is effortful proactive process. They
showed that experienced drivers suffered more in dual task assignment than
inexperienced drivers. They added, that "experienced drivers have a more sophisticated
and accurate mental model of driving than novices but this mental model demands more
cognitive resources to implement". In addition, they showed evidence that with practice
hazard perception becomes a central executive task. Automatic retrieval of past
situations occurs when attention is allocated to elements in the environment (Logan
1988). But in dynamic environment, the chance that a specific episode will fit exactly to
one in long term memory is rare and therefore, as previously mentioned (ecological
attitude), a skilled driver can reach better performance than unskilled driver but he or
she must interact between top down and bottom up process in order to reach high level
of hazard perception and they can't relay solely on schemata.

This process of maintaining proper SA is, by no means, effortful and demands
attentional resources. Horswill and Mckenna (2004) presented research showed, that
using cellular phone while driving, whether or not it was a hand free set, increased the
risk of collision. They add that sometimes, experienced drivers spare little attention for
hazard perception but when they do so they lose their hazard perception advantage. The researchers presented eye movement research which found that in demanding traffic situations, novice drivers had narrower horizontal search pattern than experienced drivers, suggesting that novice drivers have an impoverish mental model of the road environment in these conditions and that they had less expectations of where potential source of danger might arise. Wickens (2001) claimed that the direction of fixation could provide useful information about the process of maintaining situation awareness.

So far the discussion concentrated at the contribution of experience to the ability to detect hazards and to predict hazardous situations. Long term memory structures enables the skilled driver to predict and anticipate hazardous situations, it cues the driver to critical elements in the environment to efficiently direct attention to important elements in traffic environment and to integrate those elements into a holistic understanding of the environment. The next session will concentrate on the degraded ability to recognize hazards as a function of the age of the driver.

1.4.4 Hazard and risk perception in old drivers

According to Charlton and Walker (1999) in the next 20 years the numbers of 75 and 85 year olds appear set to nearly double. Vaupel and Christensen (1996) presented evidence for the growing of life expectancies and on the contrary to former assumptions, there is no upper limit for its growth. These data suggest the older population constantly grows and as a result the number of older drivers rise also. According to Rafaely et al (In press) as a result of age-related declines in sensory, perceptual, and cognitive skills, older road users may be more likely than younger adults to be involved in traffic accidents. However she also mentioned that despite these impairments, older drivers aged 70 are as likely as 40 years old drivers to be involved in a car accident. The old-driver is much more aware of its limitations and therefore, is less willing to take risks.

Much research showed that older drivers perceive traffic risks to a greater degree than young adult drivers (e.g. Sivak et al, 1989, as cited in Rafaely et al, In press). Furthermore, Rafaely et al (In press) conducted a research asking young and old drivers to estimate the number of young and older people (out of 100,000) that were fatally, severely, and mildly injured in vehicle and pedestrians' accidents in the present and in the past. Older drivers rated their risk higher than young drivers whereas the young drivers estimated their risk similar to these of the elders. The researchers concluded that the old drivers aware of their limitations and their risks increase whereas young drivers are not aware of the increase of risks resulting from age. It is important to discuss some
of the old people cognitive limitations in order to predict their performance on the road. According to Schacter (1996) damage to the frontal lobes resulting from age (usually after the age of 70) (atrophy) have mostly effect on recalling and not recognizing. He mentioned for example, that old people usually experience problems to recall a list of words rather than recognizing them when shown. He adds that old people, for example, might experience deficits to recall future action they should do but with the proper retrieval cue their performance is as good as young people. In the context of driving, old drivers should not experience any difficulties to perceive and recognize hazards while driving as long as they see the appropriate cue within the environment. The traffic environment should supply, probably without any awareness the appropriate cues for the old drivers to recognize hazards. They might experience difficulties however to respond on time due to motor limitations.

Source amnesia is also common among old people, meaning that they will remember a specific fact but without remembering who told them that fact or where they acquired that knowledge (e.g. Schacter, 1996; Bolstad and Hess, 2000). Bolstad and Hess (2000) discuss in details about situation awareness and aging. They suggest that most attentional problems attribute to older adults typically occur in novel context. Experienced old subjects dealing in domain specific tasks usually function like young subjects when most age limitations disappear. Old subjects who are experts depend on their long-term memory structure known as the schema. It enables them to focus their attention on the appropriate information and to direct their attention according to a probabilistic information attitude. According to Bolstad and Hess (2000) the schema is only minimally affected by aging and in most cases remains intact. Researchers add that episodic memory functions may be moderated by environmental support when external guidance such as traffic signs are given while the driver encodes or retrieve information.

In summary, the old-experienced driver should perceive hazards and understand the meaning of a situation well, at least as well the experienced drivers who are not old. Their meaningful experience enables them to use long-term memory and to free space in working memory to process information within the environment. These drivers, however, might experience difficulties to recall previous scenes as discussed earlier. Underwood et al (2005) examined whether older (60-75 years) and young drivers (30-45 years) observe the road differently. They show that old drivers scan the road like younger driver. The subjects in the experiment observed movies of hazard perception and had to press the button each time they recognized a danger. In general, older drivers pressed the button more often, implying that they perceived those movies as more
dangerous than their younger peers. The researchers concluded that old drivers' greater experience have exposed them to a larger number of hazards than the less experienced drivers and therefore, they were able to classify the same traffic situations with different criteria on the basis of their personal involvement with dangerous situations. Maltz and Shinar (1999) monitored eye movements of young and old drivers as they viewed a traffic scene image with a numeric overlay were numbers were located in their sequential order. The researchers showed that older participants had longer search episodes by means of more fixations but the mean fixation duration was similar to their younger peers. It seems that it takes more time for these drivers than younger drivers to understand the meaning of the information they observe.

In my study I presented six hazard perception movies to three driver's groups: 19 experienced drivers (22-30 years old), 21- novice drivers (17-18 years old), and 16 old drivers (65-72 years old) participated as paid volunteers. They were instructed to observe the movies as a driver driving a road and to press a button each time they recognize a hazardous situation. During this time all subjects were connected to an Eye Tracking System that measured their eye movements. When the first movie presentation was over subjects were instructed to observe these movies again and than to classify them into an arbitrary number of groups according to the similarity in their hazardous situation.

2 Research Goals

The main goal of the research was to examine how age and skill affect the ability to perceive hazards while driving down the road. Specifically, the study aspired to find those factors that improve hazard perception and are dependent on driving experience.

3 Hypotheses

- Experienced drivers and old-experienced drivers will be more sensitive to potential dangers than young-inexperienced drivers:
  - Old-experienced and experienced drivers will press more on the button than the young-inexperienced drivers
  - Old-experienced and experienced drivers will fixate more towards locations with high probability to dictate hazardous situations whereas young-inexperienced drivers will scan the environment randomly.
• Old-experienced drivers will respond later to planned-in-advanced events than young inexperienced and experienced drivers.

• Old-experienced drivers and experienced drivers will be able to create a holistic representation of the environment whereas young-inexperienced drivers will pay more attention to unimportant details.

4 Method

4.1 Subjects

Fifty six subjects – 19 experienced drivers (22-30 years old), 21- novice drivers (17-18 years old), and 16 old drivers (65-72 years old) participated as paid volunteers. Novice drivers had an average of 2.7 months registered driving license. Experienced drivers had a driving license with an average of 7.3 years and old drivers driving license had an average of 37.5 years. All subjects had normal vision, with uncorrected Snellen static acuity of 6/9 (20/30) or better, and normal color vision. The experienced drivers were students in Ben-Gurion University. Young-inexperienced drivers were recruited through driving schools, and the old-experienced drivers were usually retired people from the city of Beer - Sheva in Israel.

4.2 Apparatus

The experiment was conducted at the Ergonomics Laboratory in the department of Industrial Engineering and Management, Ben Gurion University. A 19" LCD screen connected to a Pentium 4 personal computer was used in order to display the different movie scenes. The subject sat at an average distance of seventy centimeters from the LCD creating a visual field of 22 degrees vertically and 26 degrees horizontally. During the experiment, the LCD resolution was 1024*768 pixels. The visual scan pattern was recorded with an eye tracking system (ETS) (Applied System Laboratories, Model 504). The system recorded the location of the visual gaze at a rate of 60Hz, with a nominal accuracy of 1 degree. Six driving scenes movies were shown to the subjects. Traffic scenes duration ranged from 30 to 60 seconds. The movies were recorded in a SONY camcorder from the driver’s perspective inside a moving vehicle. Four of the movies included at least one realized dangerous situation while the other two movies were without realized dangerous situations (No hazard situation was planned in movies 2 and 6). All movies were converted into a sequence of 760*576 pixels single frames. A C++ program was used in order to show the sequence of these single frames in a rate of 30 frames per second. This program enabled to send data to the ETS (Using the XDAT cable) that indicated each frame switch with subsequent numbers ranging from 2 to 42.
Each button press was marked with the number 1 and indicated the subject’s identification of a hazard situation. Following a press the sequence of numbers continued from the last marked number, including 1 as a part of the sequence. When the numbers sequence ended it then began again from 2 (for example, if the subject pressed the mouse when the marked frame number was 10 then the following number after “1” will be 12). This procedure enabled synchronization between the eye movements and the appropriate frame. A special USB button was utilized to mark the exact frame in which the subject recognized a hazardous situation and decided respond. The cross-hair indicating the subject's gaze point (a feature of the ETS) on the actual displayed picture was recorded on a video for further analysis of eye movements.

4.3 Procedure

Subjects were connected to the ETS after a short explanation on the experiment. The experiment was conducted in three parts (The experimental protocol for the subjects instructions can be found in appendix 10.2). The first phase included eye calibration and observing two hazard perception movies that were used to practice subjects with the experimental tasks. These movies were taken in England and the subjects were reminded that they drive on the left side of the road. This phase was important to make sure that the subjects understood the purpose of their tasks and to practice at pushing the button in response to detection of a hazard. After reading the instructions the subjects signed a statement that they agree to take part in the experiment. It is important to mention that this experiment was authorized by the human subjects review committee to make sure that the subjects are not in any kind of danger during the experiment. At the end of this phase the experimenter reassured that the subject understood his or her task.

At the second phase subjects were instructed that they are about to observe several hazard perception movies taken in Israel. They were reminded to observe the movies as drivers driving a road. Each participant observed the six movies at a randomly displayed order without knowing the exact number of movies that he or she was about to see. Each subject was exposed to a hazard definition as defined by Haworth, Symmons and Kowadlo (2000), "in terms of hazards to road users, any object, situation, occurrence or combination of these that introduce the possibility of the individual road user experiencing harm should be included. Hazards may be obstructions in the roadway, a slippery road surface, merging traffic, weather conditions, distractions, a defective vehicle, or any number of other circumstances." This definition was similar in both types of Instructions as will be explained later. Approximately Half of each subject
groups (randomly selected) were further exposed to another hazard definition: "prior to a realized danger there are preliminary events which might tacit an upcoming danger. In some of the cases the potentially danger will realized and in other cases it might be a false alarm". This means that half of each subject groups received also emphasis to pay attention to cues which might predict an upcoming danger. All drivers were instructed to observe the films from a driver’s point of view and they were also instructed to press a response button with accordance to each type of instructions. Subjects who viewed only the first hazard definition were ordered to press the button whenever they recognize a danger, a situation that subjectively requires a preventive action (subjects were told that a button press reflects any action such as hornning, braking, or wheel inclination that they would have taken in order to avoid the danger). This procedure resembled Chapman and Underwood's (1998) experimental procedure. Subject who viewed extra definition were ordered to press the button when they recognize the first cue that precedes an upcoming danger. This procedure was planned in accordance to Surry's (1974) model for dangerous situations to see whether explicit directions to pay attention to cues which might precede and forecast danger can facilitate danger recognition. Figure 4.3.1 demonstrates the second phase of the experiment procedure.

Figure 4.3.1. Second part experimental procedure.
This figure schematically describes the second part experimental procedure as verbally explained above. At the end of each branch is the question asked after each movie presentation regarding the hazards mentioned by each subject.

After each movie presentation the subject was required to answer a single question, according to the type of instructions he/she received. Those who were presented only with the first definition were asked "In your opinion what was the danger in the movie you have just seen?" Those who viewed the extra definition were asked “In your opinion, what was the first cue that indicated the imminent danger.” This question fits Surry’s (1974) model’s first phase (danger build-up) in which the driver recognizes and understands the meaning of the warning that indicates an upcoming danger (see figure 1). During this phase subjects' eye movements were recorded and synchronized with the button presses. In addition, subjects were told that the button press only indicates an action decision and therefore, they should press it only once for each dangerous situation without exerting too much force on each button press.

The third phase of the experiment included a second presentation of the same hazard perception movies in the same order as the first phase. This time subjects’ eye movements were not recorded. Each subject had to observe the same movies again in the same sequence like the first phase. Prior to the second presentation each subject was informed that at the end of this phase he or she will be required to classify the movies into an arbitrary number of groups according to their similarity in the hazardous situations they contain. This procedure was taken from Benda and Hoyos (1983). At the end of the second presentation the subject received six hardcopy pictures, each representing a single movie, and they began the classification procedure. The pictures served two purposes. The first was to help subjects to physically pile similar movies and the second to help them recall each movie. Each picture contained a retrieval cue taken from each hazardous event, except movie 2 and 6 that did not include such events. The picture from movie 6 included a snapshot from the end of movie, and the picture from movie 2 was a snapshot of the beginning of the movie (see appendix 10.3).

After subjects classified the movies they were asked to title each group that best describes it. After giving each group of pictures a title the subjects were also asked whether they could see any kind of relationship among the groups they have classified. Then they were asked to subjectively evaluate the speed in which they would have felt
comfortable to drive in each situation (movie). Furthermore, after speed evaluation subjects were once again asked to find, if any, a connection among groups of movies. This procedure was meant to examine whether subjects changed their minds regarding some of the movies classifications.

4.4 Hazard perception movies scripts

Six movies were scripted and recorded in order to evaluate subjects’ ability to detect hazardous situations. The concept of hazard in all movies was based on the theory of Situation Awareness (for further reading, see the Introduction section).

In the schematic graphic descriptions of the movies presented below the red car or arrows reflect the hazards while the blue car represents the subject's car except for scenario 6 where the white car represents the subject's car and the blue car represents one of the hazards.

4.4.1 Movie 1

This movie was taken on a fast urban road where the camera was located in a car that was tailgating another car. That means that the subject was supposed to be the driver who is tailgating. At a certain point in time the red car in front braked and made a right diversion toward a parking space on the right. This scene had two goals. First, young drivers are over involved in tailgating accidents and therefore finding differences in eye movements and subjective answers regarding this situation is important. Second, according to SA theory (Endsley, 1995) the second phase is to integrate elements in the environment in order to create a holistic representation of the current situation. Because there is no indication that the car in front is about to brake then it would be interesting to see whether the experienced drivers have any cue that might indicate an upcoming danger and that might explain some kind of holistic representation of the environment.
Moreover, Finn and Bragg (1986) found that young drivers rated tailgating less hazardous than older drivers did, and in contrast rated sudden emergence of a pedestrian in front of the driver more hazardous than did older drivers. They explained that young drivers consider tailgating as a skill and therefore they are confident that they will be able to take action when it will be necessary, while a pedestrian's sudden emergence is unexpected danger and can cause loss of control and therefore it is a dangerous situation. In that research the picture was static without any realistic hazardous situations. It would be interesting to see what happens when the car in front actually brakes. It could be for example that the young driver would be much more surprised than the experienced driver and that might explain the research results that the novice driver does not have the knowledge base of what a lead car might do and therefore they are not aware of any danger and this is why they rated tailgating as less hazardous than the experienced drivers. On the other hand the young drivers rated the pedestrian scenario more hazardous because they “know” that bumping into a human is dangerous because they are more vulnerable than a car. This knowledge is available even if the novice driver never experienced any situation in which he had to avoid a pedestrian crash.

4.4.2 Movie 2

This movie was similar to movie 1 only without a lead car. The purpose of this movie was to use same road condition as the first only without any realized danger in order to see whether experienced drivers would be more sensitive to potential hazards and therefore would be more susceptible to press the button than novice drivers.
4.4.3 Movie 3

This scenario was filmed on a densely populated residential street with cars parked on both sides. The scenario included a person riding roller blades on the pavement on the right partially hidden by parked cars, houses, and trees. This scenario was planned to examine drivers’ ability to integrate elements in the environment to achieve good SA levels 2 and 3. At a specific point in time the roller blades rider must enter the road because he is blocked by a car parked on the pavement. Drivers with high level 2 of SA should anticipate that the roller blades rider must enter the road and therefore they would press button sooner than the inexperienced drivers.

4.4.4 Movie 4

This movie is similar to scenario 3 in terms of the environmental conditions and the type of hazard (human). In this scenario a bicyclist is riding on the curved road. The subject in the moving car can observe the bicyclist right after the curve. There was a
parked car on the right side of the curb with its right wheels on the sidewalk pavement while its left wheels were on the road pavement. The brake lights of the parked car were on and served as a cue that the driver was still in the car. At a certain point in time the driver of the parked car opened the door and the bicyclists avoided it by swerving into the center of the road. An unplanned event also took place when the bicyclist later had to avoid another car parked half on the pavement and half on the road.

4.4.5 Movie 5

This movie is similar to movies 3 and 4 in terms of the road conditions (i.e. driving in narrow residential street). However, the planned-in-advanced hazardous situation in this movie involves tailgating a white car while parked cars obstruct the field of view on both sides of the road. When the lead car reaches a cross street from the right, a third car that was stopped at the intersection makes a right turn into the subject's road in front of and into the path of the lead car. As a result the lead car must brake suddenly. This movie was designed in order to examine whether drivers anticipate the sudden braking of the lead car as a result of careless driving of other cars on the road. This movie again, was designed to examine whether drivers can integrate elements within the environment in order to predict upcoming dangers. It is important to mention that it was difficult to observe the turning car because the field of view was partially hidden by parked cars.
4.4.6 Movie 6

This movie was taken in a neighborhood without any planned hazardous situations. As a matter of fact this movie is similar to movie 2 in terms of no hazardous situations. In this movie the camera was located inside a car driving on a narrow road where cars park on both sides of the road. The car drives straight and makes a right turn. Then it drives straight again and makes another right turn. No actual danger was planned or observed in this movie.
5 Results

One of the main purposes of the two types of instructions was to see whether young-inexperienced drivers could benefit from a cue explicitly given to him or her prior to the presentation of the movies. This procedure was made in order to see whether novice drivers would be more sensitive to potential hazards and would respond sooner to a materialized one. Results are presented in the same order as the experimental procedure. They are divided into three parts according to subjects' tasks.

The first part includes analysis of subjects' response to hazards and their subjective estimation of those dangerous situations according to their responses and descriptions. The second part includes the second task in which subjects were required to classify those six hazards perception movies into an arbitrary number of groups. The last part includes analysis of all titles given to those groups of hazard perception movies according to subjects' classification.

5.1 Hazardous situations sensitivity and response

5.1.1 Event attitude - general description

The main assumption in analyzing subjects' response and sensitivity to hazards was that young-inexperienced, experienced, and old-experienced drivers observe movies differently and each group type will relate differently to different situations and objects within the environment. Therefore, analyzing movies through most meaningful events (or totally not meaningful for a certain type of drivers) will help quantitatively estimate age and skill differences while driving on the road. It is important to mention that some of the meaningful events were planned in advance but others were created dynamically according to subjects’ subjective estimation. The main attitude toward analyzing results was first, to define meaningful events according subjects’ button presses (in addition to predetermined events) and then to examine those events in terms of reaction times, subjects’ sensitivity to certain events, and measuring differences in eye movements.

5.1.2 Defined events

Subjects in the experiment were instructed to observe six hazard perception movies as if they were drivers driving down the road. They were asked to press a button each time they thought that there was a dangerous situation and this response symbolizes any action they would have taken in reality in order to avoid a potential danger. The question that followed the movie changed according to two types of instructions that were designed and described in the Method section. If, for example, the
subject pressed three times in one movie he or she was required to respond to each situation according to the following questions: Those who received only one definition for hazard were asked: “you pressed the button 3 times during the movie. In each press what was the hazardous situation? Those who were exposed to the second definition were asked” In each press what was the cue that made you think that there was an upcoming dangerous situation”. All button presses and descriptions were grouped and analyzed. Table 5.1.2.1 shows all events that were observed in all movies.

Table 5.1.2.1. Planned-in-advance and unplanned-in-advance events

<table>
<thead>
<tr>
<th>Movie number</th>
<th>event</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>First parking truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Second parking truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Passing lane</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Old lady</td>
<td></td>
<td>Roller on curb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Second parking truck</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bicyclist Recognition</td>
<td>Door's car opened</td>
<td>Bicyclist 2</td>
<td>Children</td>
<td>Parking cars</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>First intersection</td>
<td>White car</td>
<td></td>
<td>White car</td>
<td>Second intersection</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>First intersection</td>
<td>Car in front</td>
<td></td>
<td>Second intersection</td>
<td>After second intersection</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.1.2.1. All events that have been observed during the experiment. All cells marked in red were those that were planned in advance. The cells without colors mark events which subjects thought were dangerous, pressed the button and described them as dangerous or potentially dangerous. Movies 2 and 6 were designed as non-hazardous movies. However, some of the subjects thought that these movies contained hazardous situations and therefore no red cell appears in those two movies but they do contain some hazardous events. Each event will be explained and analyzed later (A descriptive explanation for each event can also be found in appendix 10.4.1). Each event will be related according to its location in the matrix (e.g. Roller on curb will be called event 3_3). Furthermore, in each row of the matrix events are arranged chronologically according to their time of appearance in the movie.

5.1.3 Event importance - support and confidence

The importance of a specific event was determined according to the total number of subjects who thought the event was hazardous. High support for specific events is when most subjects thought it was dangerous as reflected by their button presses and descriptions. As expected, support for planned-in-advance events was high. However, since there was a great interest to find age and skill differences between the three groups
of drivers, it was interesting to examine events with low support that resulted from higher sensitivity of one group relative to others. I defined the confidence level of an event as the chances of a specific group to press a button when a specific event did occur. All events will be discussed in detail in the next paragraph. This procedure was made in order to decide what kind of analysis should be conducted on each event (Appendix 10.4.3 shows a detailed description for support and confidence in each event and what kind of analysis was made). The following paragraphs will describe each movie's events separately; they will also present each event analyses in terms of reaction time, types of classification, response sensitivity and eye movements (in accordance to each event characteristic), and will also include a general analysis for the six hazard perception movies.

5.1.4 Between movies – Non-event analysis

Prior to events examination an overall analysis was made in order to achieve two goals. First was to see whether movies 2 and 6 were subjectively considered less dangerous than movies 1, 3, 4, and 5 and second, to examine whether old-experienced and experienced drivers were more sensitive to hazardous situations and pressed relatively more in movies 1, 3, 4 and 5 than young-inexperienced drivers group and less in movies 2 and 6. A two-way ANOVA with repeated measures (see also appendix 10.5) demonstrated only main effect of movies' group type (average number of button presses in movies 2 and 6 versus average number of presses in movies 1, 3, 4, and, 5) where the average number of button presses was significantly higher for movies 1, 3, 4, and 5 (1.65) relative to movies 2 and 6 (1.10) \((F_{1, 53} = 55, P<0.001)\). These results show that movies 2 and 6 were subjectively considered as less hazardous then movies 1, 3, 4, and 5 by all subjects.

Chapman and Underwood (1998) demonstrated different patterns for scanning rural and urban roads. They showed that the mean fixation duration on rural roads are longer than those on urban road since urban roads contain more information per time unit. In the current research it was interesting to see whether fixation duration on movies 1 and 2 that included driving in a relatively open fast road would be longer than those in movies 3-6. A two-way ANOVA with repeated measures showed main effect for the driver type where old-experienced subjects had longer mean fixation duration (241 ms) than experienced drivers (220 ms), and young-inexperienced drivers (204 ms) \((F_{2, 36} = 6.944, p<0.003)\). In addition a significant main effect of road type revealed that indeed movies 1 and 2 elicited longer mean fixation durations (229ms) than movies 3-6
These results are similar to those obtained by Chapman and Underwood (1998).

5.1.5 Movies event analysis

This section includes a detailed analysis for each movie where some of the movies included a general eye movements' analysis to see whether there were any differences in the general scan patterns between novice, experienced, and old-experienced drivers. The last part of this section examined whether events which occurred immediately prior to and after planned-in-advance events were estimated as dangerous by more of the experienced and old-experienced drivers than by the young-inexperienced drivers. First, it is important to schematically describe the logical process utilized to analyze reaction time, type of classification, and groups' events sensitivity. The logical process is schematically described in Figure 5.1.5.1.

![Figure 5.1.5.1. Events analysis classification algorithm](image)

Figure 5.1.5.1 presents the logical process utilized to analyze the six hazard perception movies. The right two branches relate to the nature of the hazardous events which occurred in the movies. Planned events were those that were predetermined and planned-in-advance as dangerous. The unplanned events included additional events that were subjectively estimated as dangerous by some of the subjects' event though they were not planned in advance. The left branch relate first to all unplanned events in each movie that occurred prior to the planned events and all unplanned events that occurred after the planned events. There are reasons to believe that since all subjects were instructed to press the button whenever they encounter any kind of dangerous situations, young-inexperienced will press less after the planned-in-advance danger occurred.
Second, the left branch examine whether drivers responds less to intersections as hazardous situations in movies were no planned-in-advance events occurred relative to movies were planned-in-advance events occurred.

High support events were those that more than 30% of the subjects thought they were hazardous (by pressing the button). Low support events included events that 30% or less of the subjects thought were dangerous. However, low support events were interesting if all those who decided to press the button (or decided not to press the button) belonged to a specific group of drivers (showing over sensitivity). In such case eye movements’ examination and sensitivity level are important tools to examine differences between drivers groups. Furthermore, according to Endsley's (1995) SA theory, the inexperienced operator in a dynamic environment might observe the same elements as the experienced operator but will fail to integrate those elements to create a holistic representation of the situation. This difference might be reflected in each subject’s description of the same hazardous events. Examining reaction times in these planned-in-advance events might reveal differences in the speed in which each driver group responded to the same event. Measuring reaction time in low support events would be useless since only few subjects responded and usually they are from the same group. Hence, it is more interesting in such cases to examine response sensitivity.

A superficial observation revealed that first, novice drivers rarely related to events that occurred after the "planned-in-advance" events. Thus it was interesting to examine whether the young-inexperienced drivers are less sensitive to after-planned events than the two other groups of drivers. Second, it seems that in general, drivers responded less to intersections as hazardous situations if no planned-in-advance events antecedent them relative to movies were planned-in-advance events occurred prior to their appearance. The left branch of figure 5.1.3 relates to both of these issues. Some basic rules of thumb described below were used in order to associate a button press to with specific event.

Basically, subject’s button press was related to a specific event according to subject's description of the event unless the press occurred prior to the appearance of the event that the subject described. In these cases (there were only few) the press was related to the event which best matched to the frame number that was indicated by the subject. This later procedure was utilized also when subjects mentioned that they didn’t remember why they pressed the button or claimed that they accidentally pressed it.

These rules were set in order to classify properly subjects' presses. The following sub-paragraphs will present a descriptive analysis of each movie events. Some movies also include general eye movements' analysis. Appendix 10.4.3 summarizes all events
and types of analysis for each event specifically. Furthermore, response sensitivity and type of classification is summarized in appendix 10.4.4. Each movie events analysis included $X^2$ analysis for response sensitivity and type of classification, and a two way ANOVA (the two independent variables included the group of drivers and the type of instructions) to analyze reaction time and eye movements' analysis (dependent variables) to examine whether there were any scan patterns differences. Movies were made at an average of 25 fps, and analyzed by frames. The actual rate varied from 24 to 26 frames per second due to system constraints. Response analysis was made in terms of frame number indicating a specific point in which the driver decided to press the button. All frame numbers can be converted into seconds by dividing a frame number in the average rate (25 frames per sec). Since the fps was not constant all reaction times which will be presented are an average numbers of seconds. Furthermore, in the framework of the research the beginning of each hazardous situation was subjectively estimated by the participant and therefore the reaction times will represent the delay between the first group of drivers who pressed the button and the other groups. It is important to mention that all button presses were recorded both to the eye movement program and were also manually written. Some of the presses were missed and not recorded due to lack of button sensitivity. Reaction time analysis was made according to the button presses that were actually registered. Subjects' response sensitivity, however, was analyzed according to the manually recorded presses. In most cases there was a match between registered presses and manually button recordings. When a press was recorded manually along with a verbal description it was taken in consideration for the response sensitivity analysis even if no press was recorded into the computer (the main reason was not to miss important data All presses that were manually registered and were recorded into the computer were identical indicating the validity of the manual registration procedure. Therefore, the algorithm previously described relates to the support and confidence based on the manually registration procedure. Reaction times calculations however were made according to the available data registered in the computer. Therefore in some cases the reaction times calculation was based on a smaller number of observations.

Furthermore, in order to reduce the number of categories for the $X^2$ analysis, subjects' hazard descriptions with the same meaning were grouped under one category. This procedure enabled the reduction of the number of categories for the $X^2$ analysis (For a detailed description see appendix 10.6.1). The results presented next relate to all categories after they were grouped. The next table presents all $X^2$ coding signs. If $X^2$
was significant in general (Main) then groups’ paired comparison was utilized in order to find the source of the difference.

Table 5.1.5.1. Groups comparison encoding

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main</td>
<td>Each group of drivers was separately compared (O, E, Y)</td>
</tr>
<tr>
<td>Y Vs O; E Vs Y; O Vs E;</td>
<td>Each of these selected arrangements examines differences between two groups of drivers.</td>
</tr>
</tbody>
</table>

The old-experienced, experienced and young-inexperienced drivers included 16, 19, and 21 subjects respectively. O = old; E = experienced; Y = young.

$X^2$ results of response sensitivity and classification type are presented in the following way. First, each drivers group (O, E, and Y) that was compared for $X^2$ calculation will include individual details in parenthesis. Each parenthesis left-hand side represents the total number of drivers from a specific group who either mentioned the event or classified it according to a specific category. The parenthesis right-hand side presents the proportion of specific population who chose a specific category or mentioned an event from all those who chose that event or category. All event descriptions and directions are from the driver perspective. Intersections where no imminent hazard occurred were hard to analyze in terms of classification analysis since some descriptions where similar but according to reaction time they happened in different points in time. "Approaching an intersection", for example, could describe a participant who pressed relatively far from the intersection whereas same description could relate to someone who reacted much closer to the intersection. Events 2_2, 6_1, 6_3, and 5_4 where not analyzed by means of classification type analysis.

Eye movement analysis was made utilizing the ILAB free software where all fixations were calculated according to the dispersion algorithm. According to this algorithm a fixation was determined as a movement of the eye for no more than 1 visual square degree for at least 100ms. Unless the ETS lost the eye for more than 20 consecutive samples, these losses were considered as blinking. Fixation locations were set as the mean of all samples considered in a single fixation. This means that several consecutive frames might share the same fixation location. General eye movement analysis will include averaging over all eye movements through the entire selected scene while specific analysis will examine subjects' eye movements in specific frames. Fixations location will be presented in pixels and also in visual angle from the center of the road. There are some limitations that enforce only an estimation of the visual angle.
from the center of the road. The first is that each subject seat at a difference distance from the display. Second, each subject may have tilted his or hers head from the center and that may also effect the visual angle. In general the center of the road was always located at the center of the screen. This assumption is plausible since the camera was located inside a driving vehicle. The average distance between the subjects and the display was 75 cm with a standard deviation of 3 cm. This average number will be utilized to calculate the visual angle. The visual angle will be extract through the triangle between the participant eye, the center of the road, and the fixation location. This visual angle represents the average visual angle of each group of drivers. When relating to Regions of Interest the calculations included all fixations within a rectangle surrounding the center of the object, taking in consideration additional 30 pixels both in height and width to include the eye tracking 1 visual angle acuity limitation. The total number of subjects in the eye movements' calculation depends on whether subjects had fixations in the segment that was analyzed.

5.1.5.1 Movie 1 events analysis

Detailed scene description can be found in the Method chapter. In the following scene subjects view angle was designed by locating the camera inside a car tailgating a red car in a two lane urban road. The road is relatively wide and the field of view was clear. At a certain point in time the red car suddenly brakes and makes a right turn towards a free parking space on the right side of the road. The main purpose of this scenario was to examine whether experienced drivers have any kind of environmental cue or knowledge base that might cue them to the upcoming braking of the car in front. Bragg and Fin (1986) showed that young drivers rated pictures of tailgating as less hazardous than experienced drivers. In this movie a potential hazardous situation such as tailgating becomes a real danger. This event might show that young drivers rated tailgating less hazardous because they lack the knowledge base of what might happen when tailgating and therefore they might be more surprised than the other groups when a danger materializes (i.e. when the red car suddenly brakes). The movie lasted approximately 31s, containing 790 frames running at an average of 25 frames per sec.

5.1.5.1.1 Events description

Subjects determined 4 dangerous events and they are presented in a chronological order.

Event 1 - "First parking truck" (frames 136-291). In this event the subject’s car approached a truck parked on the right side of the road.

Event 2 – "Second parking truck" (frames 349-439). In this event the subject’s car approached a second truck parked on the right side of the road.
Event 3 – "Red car" (frames 554-683). In this event the red car in front suddenly braked and made a right turn towards a free parking space on the right side of the road.

Event 4 – "Intersection" (frames 743-782). In this event the subject's car was approaching an intersection.

5.1.5.1.2 Response sensitivity and classification type analysis

All tables and detailed numbers can be found in appendix 10.6.1. Results show that no group was over sensitive to press the button when the red car braked meaning that all subjects thought this was a dangerous situation. The old-experienced drivers (10 out of 13 (10/13) drivers, 71% of all drivers who mentioned it as the hazard instigator) were more sensitive the other groups to mention that the hazard instigator was the irresponsible behavior of the leading car because it didn’t signal when turning right. No difference was found between the experienced (3/17, 21%) and young-inexperienced drivers (1/17, 8%) who were much less sensitive to mention it as the hazard instigator. These drivers verbally related more to the braking action itself or the right turn of the braking car (O Vs E, \( X_1^2 = 11, P < 0.01 \); Y Vs O, \( X_1^2 = 11, P < 0.01 \); E Vs Y, \( X_1^2 = 3.83, P < 0.2 \)). Only 3 out of 16 experienced drivers (21%) and 1 young-inexperienced driver out of 12 drivers (7%) mentioned a signaling problem.

Approaching the intersection was analyzed only in terms of response sensitivity and showed that the old-experienced (4 out of 16 drivers (4/16), 36% of all drivers who pressed the button in this event) and experienced drivers (6/19, 55%) were more sensitive than the young-inexperienced drivers (1/21, 9%) to press the button though the only significant difference was found between experienced and young-inexperienced drivers (O Vs E, \( X_1^2 = 0.18, P < 1 \); Y Vs O, \( X_1^2 = 3.18, P < 0.1 \); E Vs Y, \( X_1^2 = 4.97, P < 0.05 \)).

5.1.5.1.3 Reaction time analysis

Event 1_3 begins at frame 554. Analyzing reaction time when the red car braked revealed that only group type main effect was significant (\( F_{2, 40} = 14.147, P < 0.001 \)). Old-experienced drivers were the slowest to respond (Average Frame Number (AFN) = 639.3). No difference was found between the experienced (AFN=585.4) and young-inexperienced drivers (AFN=591.4). Transforming the frame number to seconds, the old-experienced drivers responded on the average in 2.15 seconds later than the experienced drivers and on the average in 1.91 seconds later than the young-inexperienced drivers. According to these results old-experienced drivers pressed the button when the red car was already half way inside the parking space on the right whereas the young-inexperienced and the experienced drivers pressed the button when
the car was still in front and in the center of the right lane right after its brake lights turned on.

Figure 5.1.5.1.3.1 presents the average frame number in which the old-experienced, young-inexperienced and experienced drivers pressed the button and the Average Response Latency (ARL) in seconds of the old experienced drivers relative to others.

<table>
<thead>
<tr>
<th>AFN 588</th>
<th>AFN 639 (ARL= 2 sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experienced and young-inexperienced drivers</td>
<td>Old-experienced drivers</td>
</tr>
</tbody>
</table>

Figure 5.1.5.1.3.1. Drivers’ reaction time to the braking car episode.

These results emphasize old-experienced drivers' perspective for danger, and their need for cues (like signaling) that will inform them sooner of other road users' intentions. These drivers perceived the hazard as a signaling problem whereas young-inexperienced and experienced drivers perceived the brake itself as the hazard (It was also demonstrated in their hazard descriptions). It seems that the old-experienced drivers were more sensitive to the cause of the danger prior to pressing the button, yet they still responded slower.

5.1.5.1.4 Eye movement analysis

Movie 1 was interesting since it included driving in the right lane in a two carriageway urban road following a leading car while cars were parked on the right side of the road. The distance between the lead car and the following car was relatively constant from the moment the red car approached the parking cars (frame 306) until it braked (frame 536) and therefore the information flow rate was relatively similar for all frames until the red car turned right. Furthermore, the lead car was always at the center of the road (X=479 pixels), through the all section where eye movements were calculated (frame 306- frame 536). Drivers whom their standard deviation was larger than 1024 pixels where not analyzed (1 experienced and one old-experienced driver). Analyzing the mean horizontal fixation location using a one way ANOVA showed that both old-experienced drivers (8 drivers) and experienced drivers (14 drivers) looked
significantly more towards the right side (O-516.1 pixels, an average of 1.26 Visual Degrees from the Center of the Road (VDCR); E-514.3 pixels, VDCR=1.21) than the young inexperienced (488.7 pixels, VDCR=0.49) drivers (15 drivers) \( (F_{2, 34}=3.87, P<0.03) \). Young-inexperienced drivers tended to fixate more on the leading car while occasionally fixating on parked cars on the right.

It seems that with experience drivers adopt the most useful visual scan patterns to observe the road. Directing the gaze between the parked cars and the leading car enables them to attend to both the leading car and to potential hazards that might appear between the parked cars.

In summary, all drivers were equally sensitive to respond when the red car braked and turned right. The old-experienced drivers however, were slower to respond than all other groups and related more to a signaling problem of the lead car. Other drivers related more to the braking itself as the hazard instigator. Eye movements' analysis revealed that old-experienced and experienced drivers were highly attended to the lead car but also to the parked car on the right side of the road. Young-inexperienced drivers tended to concentrate at the lead car. Approaching to the intersection only experienced and old-experienced drivers responded to the intersection though only experienced drivers were significantly different from the young-inexperienced drivers. Old-experienced drivers were not significantly different from any of the other groups.

### 5.1.5.2 Movie 2 events analysis

Scene detailed description can be found in the Method chapter. This scene served as a control for other movies which contained planned-in-advance hazardous situations. This movie included driving a road with similar conditions demonstrated in movie 1 only without any materialized hazardous situation instigated by other road users. The camera was located inside a car, driving in a two lane carriageway urban road. Subject's car was driving on the right side of the road and then moved from the right to the left lane approaching a red light before an intersection. The basic assumption was that drivers will rarely indicate any hazardous situations in this movie since it didn’t contain any planned-in-advance events. The movie extended approximately 25s containing 702 frames running at an average of 25 frames per sec.

#### 5.1.5.2.1 Events description

Subjects determined 2 hazardous events and they are presented in a chronological order.

**Event 1 - "Passing lane"** (frames 413-488). In this event the subject's car moved from the right lane to the left lane of the road.
Event 2- "Intersection" (414-631). In this event the subject’s car approached signaled intersections where the color was red.

5.1.5.2.2 Response sensitivity and classification type analysis

All tables and detailed numbers can be found in appendix 10.6.2. Event 2_1 was not analyzed since it has a low support and no group was over sensitive to respond. All drivers were highly and equally sensitive to mention the high supported 2_2 event as hazardous but it was not analyzed in terms of classification type analysis.

5.1.5.2.3 Reaction time analysis

Analyzing event 2_2 revealed only main effect ($F_{2, 23}=3.522, P<0.046$) for group type. Old-experienced drivers were slower to respond (AFN=565.5) when approaching the intersection than the experienced drivers (AFN=502.6). The young-inexperienced drivers (AFN=540.4) were not significantly different either from the old-experienced or the experienced drivers. Transforming the frame number to seconds, the old-experienced drivers responded on the average in 2.51 seconds later than the experienced drivers and on the average in 1 second later than the young-inexperienced drivers.

Furthermore, results demonstrate that old-experienced drivers pressed the button much closer to the intersection than the experienced drivers who pressed the button relatively far from the intersection.

5.1.5.2.4 Movie 2 additional analysis

Movie 2 in which no hazard situation was planned-in-advance was classified by experienced drivers as more dangerous than the other groups. Only 2 out of 19 experienced drivers (2/19) (10% of all drivers who didn’t press the button in this event) thought this movie was not dangerous at all and it was significantly less from old-experienced (7/16, 35%) and young-inexperienced (11/21, 55%) drivers who thought this movie was not dangerous (E Vs O, $X^2=5.02, P<0.05$; E Vs Y, $X^2=7.96, P<0.01$; O Vs Y, $X^2=0.27, P<1$).

In summary, all drivers were highly and equally sensitive to mention the intersection event as hazardous (event 2_2). The only reaction times difference was found between the old-experienced drivers and the experienced drivers. The old-experienced drivers were much slower to respond than the experienced drivers. Young-inexperienced drivers were not different from any of these groups. Experienced drivers were significantly more sensitive to classify this movie more hazardous than all other groups of drivers.
5.1.5.3  Movie 3 events analysis

Scene detailed description can be found in the Method chapter. This movie was planned in order to examine the efficiency in which drivers integrate elements in the environment at a certain point in time, understands the meaning of it, and predict a near-future hazardous situation. This movie was aiming to examine level 2 and 3 in Endsley's (1995) SA theory. Movie 3 was filmed in a narrow residential road where cars were parked on both sides of the road.

5.1.5.3.1  Events description

Subjects determined 4 dangerous events and they are presented in a chronological order.

Event 1 - "Old-Lady" (frames 39-167). In this event the subject's car was driving along the road and at a certain point in time an old lady with a basket was walking on the right side of the road next to the parked cars.

Event 2 - "Roller on Curb" (frames 281-380). In this planned-in-advance event an adult using roller-blades was driving on the right curb. Subjects who pressed the button in this event detected the roller while he was still on the right curb. The roller blader was also hidden behind some trees and vehicles that parked on the right side. This event was determined according to the following heuristic: All old-experienced drivers who detected the roller blader while driving on the curb pressed the button also when he entered the road. The minimal frame number indicating the roller blader entrance to the road was 381. Therefore, the roller was considered as entering the road at this point even though the actual entrance occurs at frame 397. Hence, the roller blader is considered on the curb until he turns his back towards the road (frame 371 plus 10 frames to allow those who recognized him on the curb to respond).

Event 3 - "Roller on Road" (381-464). The roller blader’s intention was clear when he turned his back towards the road. At frame 381 the roller begins his movement towards the road. Again this point was determined according to previous event.

Event 4 - "Intersection" (frames 634-686). Some subjects pressed the button when they approached the T intersection after the subject’s car passed the roller blader and he left the scene.

5.1.5.3.2  Response sensitivity and classification type analysis

All tables and detailed numbers can be found in appendix 10.6.3. Results shows that old-experienced (3 out of 16 (3/16 drivers, 43% of all those drivers who pressed the button in this event) and experienced (4/19, 57%) drivers were more sensitive to press the button while the roller was on the curb. In fact, no young-inexperienced driver
pressed the button in this event (event 3_2) (O Vs E, $X_1^2 = 0$, $P< 1$; Y Vs O, $X_1^2 = 4.3$, $P< 0.05$; E Vs Y, $X_1^2 = 4.9$, $P< 0.05$). When the roller blader entered the road no difference was found between the groups by means of response sensitivity. Most subjects thought this event was dangerous.

Since only the experienced and old-experienced drivers were sensitive to press the button when the roller blader was still on the curb (event 3_2) it was interesting to observe whether those subjects that pressed on event 3_2 pressed also on event 3_3. Results demonstrate that all experienced drivers (4 out of 4 drivers (4/4)) who pressed the button on event 3_2 didn’t press on event 3_3 whereas all those old-experienced drivers (3/3) who pressed on event 3_2 also pressed on event 3_3 (O Vs E, $X_1^2 = 7$, $P< 0.01$).

After the planned-in-advance dangerous event materialized, only experienced (5 out of 19 (5/19), 50% of all drivers who pressed the button in this event) and old-experienced (5/16, 50%) drivers were sensitive to press the button when they approached the intersection (event 3_4) (O Vs E, $X_1^2 = 0.1$, $P< 1$; Y Vs O, $X_1^2 = 7.6$, $P< 0.01$; E Vs Y, $X_1^2 = 6.3$, $P< 0.025$). None of the young-inexperience driver pressed the button on this event.

5.1.5.3.3 Reaction time analysis

Reaction time analysis revealed no significant difference either by means of type of instructions or driver type. The average frame number pressed by the three groups of drivers was O-407.1, E- 401.2, and Y- 402.4. These results suggests that when the danger is discovered all subjects press at about the same time.

5.1.5.3.4 Eye movement analysis

Eye movements' analysis was interesting for two reasons. The first was to demonstrate that old-experienced and experienced drivers discerned the Roller-blader while he was still on the curb. The second reason was to examine whether experienced and old-experienced drivers observe intersections differently than young-inexperienced drivers. Specifically, experienced drivers search for potential hazards that may suddenly appear from the right side of an intersection, while inexperienced drivers fail to do so.

Figure 5.1.5.3.4.1 demonstrates the visual search patterns of each driver groups on frames 340-400 divided into 3 segments 340-360, 360-380, and 380-400 respectively. All fixations within each frames segment are presented on the last frame of each segment (360, 380, and 400 respectively).
The green, red and blue circles represent experienced, old-experienced and young-inexperienced drivers respectively. The left column present frames 360, 380 and 400 from top to bottom without superimposing fixations. The right column presents these same frames but with fixations superimposed. The circles include all fixations from all subjects. The eye movement analysis on these segments included 14 experienced (15 on frames 380 and 400), 10 old-experienced and 15 young-inexperienced (16 on frames 380 and 400) drivers.

A one-way ANOVA on frames 340-360 (the roller blader skated on the curb) revealed that the mean horizontal fixation location was significantly different between the experienced (704.2 pixels, VDCR=3.78) and the young-inexperienced (618.6 pixels, VDCR=1.37) drivers while the old-experienced (660 pixels, VDCR=2.54) were not
significantly different from any of other groups \((F_{2, 36}=4.55, P<0.017)\). Specifically, examining fixations in the Region of Interest (ROI) that included a rectangle (width-50 pixels, Height-100 pixels surrounding the roller blader) revealed that experienced drivers were more susceptible to fixate on the roller blader (10 drivers out of 14 drivers (10/14)) than the young-inexperienced drivers (5/15). Old-experienced drivers were no different from any of these groups (4/10) \((O \text{ Vs } E, X_1^2 =2.37, P<0.2; \ Y \text{ Vs } O, X_1^2 =0.11, P<1; \ E \text{ Vs } Y, X_1^2 =4.2, P<0.05)\). This means that the experienced (also the old-experienced yet not significant) drivers detected the roller blader while he was still hidden on the curb.

Furthermore, there was a significant difference in the mean fixation duration in this segment where old-experienced drivers (204.75ms) had greater fixation duration than the young-inexperienced drivers (147.05ms) \((F_{2, 36} = 4.884, P<0.013)\). The experienced drivers (179ms) were not different from any of these groups.

Frames 360-380 analysis demonstrated no difference in the mean horizontal fixation location implying that in this segment all drivers noticed and paid attention to the roller blader. Examining the mean fixation duration revealed a significant difference between the old-experienced (266.45ms) drivers and the young-inexperienced (170.5ms) and the experienced drivers (154.3 ms) \((F_{2, 38} = 6.8, P<0.003)\). Specifically, examining fixations in the Region of Interest (ROI) that included a rectangle (width-70 pixels, Height-110 pixels surrounding the roller blader) revealed that experienced drivers were equally susceptible to fixate on the roller blader (11 drivers out of 14 drivers (11/14)) and were no different from the young-inexperienced drivers (11/15) and to the old-experienced drivers (6/10) \((O \text{ Vs } E, X_1^2 =0.49, P<1; \ Y \text{ Vs } O, X_1^2 =0.21, P<1; \ E \text{ Vs } Y, X_1^2 =0.08, P<1)\).

The last segment (frames 381-464) showed no difference in the horizontal mean fixation location but did again show a significant difference between the mean fixation duration of the old-experienced (227.5ms) and the young-inexperienced drivers (160.45ms). The experienced drivers were not different from any of these groups \((187.7ms) \ (F_{2, 38}=3.47, P<0.047)\). Specifically, examining fixations in the Region of Interest (ROI) that included a rectangle (width-70 pixels, Height-130 pixels surrounding the roller blader) revealed that all drivers (O-10/10, Y-16/16, and E-15/15) fixated on the roller blader.

Analyzing mean horizontal fixations location on frames 602-630 (road emerge from the right) revealed that both the experienced drivers (16 drivers, 561 pixels, VDCR=1.33) and the old-experienced drivers (11 drivers, 589.1 pixels, VDCR=2.11)
tended to turn their gaze toward the right side of the intersection while the young-inexperienced drivers tended to look more straight forward (16 drivers, 526 pixels, VDCR=0.34) ($F_{2, 40}=6.48, P<0.004$). Figure 5.1.5.3.4.2 presents all fixations on these frames superimposed on frame 605.

![Figure 5.1.5.3.4.2. All fixations from frames 605-630 superimposed on frame 605](image)

The blue circles demonstrate novice fixations and it can be seen that they spread more evenly between the left and the right side whereas the experienced and old-experienced drivers (green and red circles respectively) tend to look more towards the right side, with accordance to their predetermined schema, where a potential danger is with high probability to appear.

In summary, when the roller blader was hidden at the first segment only the experienced drivers (and some old-experienced drivers) detected him as demonstrated from their eye movements. When the roller blader was more salient but still on the curb, most drivers detected him but only experienced drivers and old-experienced drivers were sensitive enough to press the button. When the roller blader entered the road all subjects detected him and pressed the button. Experienced drivers related to the roller blader episode as one event whereas old-experienced responded both when the roller was still on the curb and when he entered the road. In general, Old-experienced drivers had longer fixation duration than the other groups and might indicate that they need more time in order to process information. Furthermore, approaching an intersection revealed that old-experienced and experienced drivers directs their gaze toward the right side of the intersection where a road emerges whereas young-inexperienced drivers direct their gaze straight forward.
5.1.5.4 Movie 4 events analysis

Scene detailed description can be found in the Method chapter. This movie was aimed to examine the efficiency in which drivers integrate elements in the environment at a certain point in time, understands the meaning of it and predicts a near-future hazardous situation (level 2 and 3 in Endsley's (1995 SA theory). Movie 4 was filmed inside a neighborhood where cars park on both sides of a curved road. The subject's car was driving along that road until it approached a T intersection. This movie was similar to movie 3 in terms of environmental conditions.

5.1.5.4.1 Events description

Event 1 - "Bicyclist Recognition" (frames 91-216). In this event the subject's car was driving along a curved road and at a certain point in time- right after the curve- a bicyclist appeared driving in the right side of the road.

Event 2 - "Car's door opened" (frames 224-286). In this planned-in-advance event there was a parked car- with its brake lights on- parked half on the curb and half on the road. Once the bicyclist approached to the parking car the driver opened the car's door and the bicyclists avoided it by turning left into the center of the road.

Event 3 - "Bicyclist_2" (385-483). This event was not planned-in-advance. However, most of the drivers pressed the button when the bicyclist, once again, turned left to the center of the road when he avoided a parked car on the right side of the road that half of it parked on the curb.

Event 4 - "Children" (frames 508-533). After the bicyclist left the scene two young children were walking on a narrow curb on the right side of the road without to enter the road.

Event 5 - "Parking cars" (frames 586-657). This event occurred nearly at the end of the movie were some subjects pressed the button, to mention that there were parked cars on both sides of the road.

5.1.5.4.2 Response sensitivity and classification type analysis

All tables and detailed numbers can be found in the Method chapter. Results show that all subjects were sensitive to press the button when the bicyclist was discovered after the curve (Event 4_1). This was not planned-in-advance event but most subjects responded to it. When the planned-in-advanced event occurred and the parked car's door opened (event 4_2), the experienced drivers were significantly less sensitive (11 out of 19 drivers (11/19), 25% of all drivers who pressed the button in this event) to press the button than the young-inexperienced drivers (18/21, 42%). The old-experienced drivers
were not different from any of the other groups (14/16, 33%) (O Vs E, $X^2_1 = 3.73, P< 0.1$; Y Vs O, $X^2_1 = 0.08, P< 1$; E Vs Y, $X^2_1 = 3.87, P< 0.05$).

Further analysis revealed that from those who pressed the button when they first recognized the bicyclist (event 4_1) the experienced drivers were significantly less sensitive (only 5 experienced drivers pressed the button also in event 4_2 from all 11 who pressed the button in event 4_1, 28% of all drivers who pressed the button twice on these events) to press the button again-when the car’s door was opened by the driver-than the old-experienced driver (5/5, 28%) (O Vs E, $X^2_1 = 4.36, P< 0.05$). The young-inexperienced (8/11, 44%) were not different from either of the two other groups. In fact the old-experienced drivers always pressed the button when the door was opened even if he or she recognized the bicyclist earlier. Though not significantly different, only 3 of the 11 young-inexperienced drivers who did press the button on event 4_1 did not press again on event 4_2. These results might imply that the experienced driver related to the bicyclist events 1 and 2 as one continuous event (like events 3_2 and 3_3) whereas other groups related to these events separately.

Event 4_3 where the bicyclist entered the center of the road the second time was by no means important for all groups and there was no difference in their response for this event.

When the two children walked on the curb (event 4_4) only the experienced and old-experienced drivers were sensitive to press the button. However, only the old-experienced (3 out of 16 drivers (3/16), 60% of all drivers who pressed the button in this event) and the young-inexperienced (0/21, 0%) were significantly different while experienced drivers (2/19, 40%) were not statistically different from either of these groups (O Vs E, $X^2_1 = 0.48, P< 1$; Y Vs O, $X^2_1 = 4.28, P< 0.05$; E Vs Y, $X^2_1 = 2.33, P< 0.2$). It is important to mention however that first, none of the young-inexperienced drivers ever mentioned those children walking on the curb whereas one experienced driver who did not press the button said that he was not afraid from those children because he saw their faces and therefore, he could predict their movements and he would have acted if necessary.

5.1.5.4.3 Reaction time analysis

Events 4_1, 4_2 and 4_3 showed no difference between subjects’ reaction time to these events. Events 4_1 and 4_2 would have been related as one event if a distinguished part of the subjects (especially the old-experienced and the young-inexperienced drivers) did not press twice (once when they recognized the bicycle and the second time when it opened the door). The standard deviation in event 4_1 was
relatively large (O- 45.2 frames, E-30.5 frames, and Y-30.6 frames) and might imply that this event was estimated subjectively by each subject as hazardous situation at a different point in time with relatively different average frame number press between subjects (O-141.4, E-163.6, and Y-178.73). Event 4_2 however, where the car's door was opened was considered hazardous by all subjects at about the same frame (O-251, E-248, and Y-251)-when the bicyclist avoided the car's door- with relatively small standard deviation (O-16.5 frames, E-16.1 frames, and Y-18.8 frames).

5.1.5.4.4 Eye movement analysis

Eye movements' analysis aimed to examine whether all driver groups have noticed the children walking on the curb. Most subjects have noticed the children and there was no significant difference between them. All fixations on frames 498-530 were calculated and those whose location was falling in the children's area of interest (taking in consideration a 1 degree error that is ~30 pixels) were taking in consideration. All drivers have noticed the children according to eye movements.

Figure 5.1.5.4.4.1 demonstrates all fixations from 13 experienced, 7 old-inexperienced and 15 young-inexperienced drivers superimposed on frames 500 and 525. The mean cumulative fixation duration on the children was 638ms for the old-experienced, 427ms for the experienced and 494ms for the young-inexperienced drivers. No significant difference was found among groups.

![Figure 5.1.5.4.4.1. Frames 500 and 525 with and without fixations superimposed.](image-url)
The left column presents frames 500 and 525 from top to bottom respectively and the right column is the same pictures with all fixations superimposed. The green circles represent the experienced fixations, the blue represent the young-inexperienced drivers and the red represent the old-experienced drivers’ fixations. Same fixations are superimposed once on frame 500 and once on frame 525.

These pictures suggest that all subjects observed the children walking on the curb but only the experienced and old-experienced drivers were sensitive enough to respond.

In summary, experienced drivers related to the bicyclist episode as one continuous event whereas young-inexperienced and old-experienced drivers related to the bicyclist episode as two separate events. When the hazard was salient and imminent all drivers responded and at about the same time. Eye movements’ analysis revealed that all drivers detected the pedestrians walking on the right curb but only experienced and old-experienced drivers were sensitive enough to respond. It will be later postulated that even though both old-experienced and young-inexperienced drivers related to the bicyclist episode as two events they did it from different reasons.

5.1.5.5 Movie 5 events analysis

Scene detailed description can be found in the Method chapter. This movie was aimed to examine the efficiency in which drivers integrate elements in the environment at a certain point in time, understands the meaning of it and predicts a near-future hazardous situation (levels 2 and 3 in Endsley's (1995) SA theory). The movie was filmed in a residential area where cars parked on both sides of the road. The subject's car tailgated after a lead car. After a while the lead car had to suddenly break because a third car entered its driving route from a vertical road on the right.

5.1.5.5.1 Events description

Event 1 – "First intersection" (frames 25-165). This unplanned event occurred right after the movie began when the leading car (and the subject's car after) passed a small intersection.

Event 2 - "Brake" (frames 192-339). This planned-in-advanced event occurred when the leading car was passing a second intersection and a third car blocked its driving route by entering from the right directly to the leading car trajectory.

Event 3 - "Mazda turn right" (451-503). This unplanned event occurred when the leading car, the Mazda, decided to turn right on the third intersection.
Event 4 - "Second Intersection" (665-771). Second Intersection represents the second intersection description given by the subjects. In fact, it was the forth intersection in the movie when the subject's car approached a T intersection at the end of the movie.

5.1.5.5.2 Response sensitivity and classification type analysis

All tables and detailed numbers can be found in appendix 10.6.5. Only events 5_2 and, 5_3, and 5_4 were analyzed by means of reaction time and response sensitivity. All subjects were equally sensitive and pressed the button when the leading car was braking as a result from the third car entering the road (event 5_2). The reason for pressing the button was different however between the old-experienced group who almost did not relate to the leading car sudden braking as the cause for the hazardous situation (2 drivers out of 14 drivers related to the braking itself (2/14), 8% of all drivers who pressed the button in this event) whereas the experienced (11/19, 46%) and the young-inexperienced (11/21, 46%) drivers related more to the braking itself (O Vs E, $X_1^2 =6.42, P< 0.025$; Y Vs O, $X_1^2 =5.22, P< 0.025$; E Vs Y, $X_1^2 =0.12, P< 1$). The majority of the old-experienced drivers (12/14, 40%) mentioned the emerging car from the right as the cause of the danger.

The young-inexperienced drivers were significantly more sensitive to press the button on event 5_3 (10 out of 21 (10/21), 67% of all drivers who pressed the button in this event) -where the leading car signaled and made a right turn-than the experienced drivers (2/19, 13%). The old-experienced drivers were not different from any of the other groups (3/16, 20%) (O Vs E, $X_1^2 =0.48, P< 1$; Y Vs O, $X_1^2 =3.32, P< 0.1$; E Vs Y, $X_1^2 =6.54, P< 0.025$).

5.1.5.5.3 Reaction time analysis

Analyzing planned-in-advance event 5_2 revealed no significant difference in reaction time between drivers. The mean frame number press was relatively similar among groups and might imply that all of them related to the same situation that is when the third car emerged from the right and the lead car braked (O-230.8, E-221.19, and Y-219).

Analyzing event 5_4 when the subject's car approached the intersection revealed no difference among subjects' reaction times (AFN) (O-715.4, E-731, and Y-737). This result is different from the results in the control-movies intersection episodes in which the old-experienced drivers were much slower to respond than the experienced-drivers.
5.1.5.5.4 Eye movement analysis

Eye movements’ analysis aimed to examine whether drivers "sense" the upcoming danger, direct their gaze and activate their predetermined schema for visually scanning the road. All subjects' fixations (E-17 drivers, O-11 drivers, and Y-16 drivers) were calculated between frames 160-178 in order to examine subjects' eye location prior to the emergence of the white car from the right, approaching an intersection. Results demonstrate a significant difference in the mean horizontal fixations locations were young-inexperienced drivers tended to look left from the leading car (462.6 pixels, VDCR=-0.83 (left)) whereas experienced (512.8 pixels, VDCR=0.59) and old-experienced (523.5 pixels, VDCR=0.89) drivers directed their gaze more towards the right were the road emerged from the right ($F_{2, 41}=8.07$, $P<0.001$). A significant difference was also found in the mean fixations duration were the old-experienced drivers had relatively larger fixations duration (235.8ms) than the novice (172ms) and the experienced drivers (182ms) ($F_{2, 41}=4.08$, $P<0.024$).

Figure 5.1.5.5.3.1 presents all subjects fixations on frame 170. It is important to mention that these locations share 17 consecutive frames but if ones wants to demonstrate the process of visual search, this picture might do the work assuming that the information flow does not change between these frames.

![Figure 5.1.5.5.3.1. All fixations on frames 160-178 superimposed on frame 170](image)

The green and red circles represent experienced and old-experienced drivers' fixations location respectively. The blue circles represent young-inexperienced fixations. The young-inexperienced drivers who lacked a proper schema and past knowledge paid more attention to the leading car and to the woman walking on the left side on the curb (frame 170 presents only the woman hand leaving the driver's visual field on the left). Only two fixations from all 16 young drivers were directed to the right side of the intersection.
In summary, when the lead car suddenly braked after the third car entered from the right all subjects responded at the same time. The reason for responding was different however between the old-experienced drivers and the other groups. The old-experienced noted that the hazard instigator was the third car whereas other groups related to the sudden brake of the lead car as the instigator. When the lead car signaled right turn only the experienced drivers did not respond. This result is similar to the results in events 3_2/3_3 and 4_1/4_2 where experienced drivers related to these episodes as one continuous event while the old-experienced drivers separated it into two events. In all of these episodes the instigator of the hazard remained in the scene in all pairs of events. Approaching to an intersection revealed no difference in response time between the driver groups. This result is different from all other intersections episodes where response time was measured. Eye movements' analysis revealed that old-experienced and experienced drivers gaze towards the right side of the intersection searching for potential hazards while the young-inexperienced drivers gazed left from the center of the road.

5.1.5.6 Movie 6 events analysis

Scene detailed description can be found in the Method chapter. This movie used as a control (without any planned-in-advance events) in order to examine subjects' sensitivity to hazards. Subject's car began driving in a one-way street, then made a right turn into a two-way road and at the second intersection it again made a right turn towards a one-way road.

5.1.5.6.1 Events description

Event 1 – "First intersection" (frames 155-310). This unplanned event occurred when the subject's car approached an intersection before it made a right turn into a two-way road. There was a no entrance traffic sign in front of the driver.

Event 2 - "Car in front" (466-509). This event occurred after the subject's car made its first right turn into a two-way street and then a car came from the opposite direction.

Event 3 - "Second intersection" (521-641). This unplanned event occurred when the subject's car made its second right turn from a two-way street into a one-way street.

Event 4 - "After second intersection" (frames 646-697). This unplanned event took place right after the subject's car made its right turn. The subject’s car took a wide turn and it looked as if it is going to hit a parking car.
5.1.5.6.2  Response sensitivity and classification type analysis

All tables and detailed numbers can be found in appendix 10.6.6. Analyzing events 6_1, and 6_3 revealed that all subjects were equally sensitive to press the button. Event 6_2 and 6_4 had low support and sensitivity and therefore were not analyzed.

Event 6_1 and 6_3 were not analyzed in terms of classification type analysis since it was impossible to understand the cause for subjects' responses.

5.1.5.6.3  Reaction time analysis

Analyzing event 6_1 revealed that the old-experienced drivers responded later to the intersection (AFN=250.3) than the experienced drivers (AFN=210) ($F_{2,37} = 4.753$, $P<0.015$) but were not different from the young-inexperienced drivers (AFN=233.5). Transforming the frame number to seconds, the old-experienced drivers responded on the average in 1.61 seconds later than the experienced drivers and on the average in 0.67 seconds later than the young-inexperienced drivers.

Figure 5.1.5.6.3.1 presents the average frame number in which each group pressed the button and the Average Latency in Response (ARL) in seconds of the old experienced drivers relative to others.

![Figure 5.1.5.6.3.1. AFN and ARL for all drivers’ groups in event 6_1](image)

Experienced drivers (AFN=210)  
Young-inexperienced drivers (AFN= 233)

Old-experienced drivers (AFN = 250, ARL=1.61 (O Vs E), ARL=0.67 (O Vs Y)
These pictures visually show the average frame number in which each of the driver groups responded to the hazardous situation. According to these pictures one can see that the young-inexperienced drivers responded in the average when the blue car was in the middle of the intersection. Old-experienced drivers were slower to respond than the experienced drivers when they approached the intersection.

Event 6_3 also demonstrated significant difference between the old-experienced drivers who responded closer to the intersection (AFN=589.8) and the experienced drivers who responded further from the intersection (AFN=552.25) \((F_{2, 20}= 3.808, P<0.04)\). No difference was found between these two groups to the young-inexperienced population (AFN=566.6). Transforming the frame number to seconds, the old-experienced drivers responded on the average in 1.5 seconds later than the experienced drivers and on the average in 0.93 seconds later than the young-inexperienced drivers. Once again results demonstrate a similar phenomenon while the experienced are first to press the button when approaching an intersection, then the young-inexperienced and lastly the old-experienced.

In summary, this control movie showed that all subjects had similar sensitivity to all highly supported events. These events included intersections. Old-experienced drivers were slower to respond in these events than the experienced drivers but not from the young-inexperienced drivers that where not different from any other group.

5.1.6 Before/After- planned-in-advance- events' analysis.

This analysis was highly important and conducted in order to see whether young-inexperienced drivers are as Endsley (1995) claimed, “helpless seekers of information within the environment”. Subjects in the experiment were instructed to search for hazards and to press a button each time they recognize a hazardous situation. A superficial observation of the data revealed that most young-inexperienced drivers tended to press the button less than the other two groups in response to the events after the planned-in-advance events. The number of after planned-in-advance events was higher than the before planned-in-advance events as can be seen from table 5.1.2.1. This means that the more hazard-sensitive subjects would press more after the planned-in-advance events than before planned-in-advance events. Furthermore, all "Before/After" events included only events in which the instigator of the danger of the planned-in-advance events left the scene (after) or had not yet appeared on the scene (before).
In order to examine this hypothesis all button presses prior to the planned-in-advanced events were summarized for each subject and compared with all button presses that appeared after the planned-in-advanced events. A two-way ANOVA with repeated measures was utilized in order to examine this hypothesis. Results showed two significant main effects which included group type ($F_{2, 53}=4.078, P=0.023$) and the within subjects factor before and after events ($F_{1, 53}=12.405, P<0.001$) and the interaction between these two variables ($F_{2, 53}=3.085, P<0.054$).

Figure 5.1.6.1 presents this interaction. Movies 2 and 6 were not taken in consideration for this analysis because they didn’t contain any planned-in-advanced events.

The young-inexperienced drivers were much less sensitive than the other driver groups to potential dangers as reflected by the relatively small average number of presses in response to the unplanned events and they were especially and significantly less sensitive to respond to unplanned events that occurred after the planned-in-advance events. Experienced and old-experienced drivers were more sensitive to unplanned
events that happened after the planned-in-advance events than unplanned events that occurred prior to the planned-in-advance events.

Most salient result is that the experienced and old-experienced drivers gave much more importance to the after planned-in-advance events and this big difference relative to the importance given to events before planned-in-advance events cannot solemnly be explained by a single episodic difference between before and after planned-in-advance events. Examining the nature of the unplanned-in-advance events which happened after the planned-in-advance events revealed that 3 intersection events appeared in the "After" events relative to only 1 intersection in the "Before" events. Old woman walking on the road in the before events resembled the children walking on the curb in the after events. All other events included parked cars. Intersection episodes and children walking on the curb created the most significant difference between the experienced drivers (either old or not) and the young-inexperienced drivers (see appendix 10.6.7). The next analysis examines drivers' behavior at intersections in details.

Both experienced and old-experienced drivers detect potential hazards. They are afraid of potentially dangerous situations since they are not sure which script they may use or because they are aware of possible deleterious outcomes which these events may produce. Young-inexperienced drivers are less sensitive to intersections and pedestrians walking on the curb.

5.1.7 Intersections response sensitivity

This section examines how drivers perceive intersections according to their nature. This analysis is based on post examination and therefore will have to be further validating in future research. The intersections are divided into three categories according to two criterions. The first relates to whether a meaningful highly supported event antecedent the intersection and the second is whether the subject's car physically entered the intersection.

- Type A- these intersections include two intersection events (1_4 and 3_4). These events occurred after a meaningful and materialized hazard and in both intersections the subject's car did not physically entered the intersection.
- Type B- these intersections include two intersection events (6_1 and 2_2). No meaningful hazard antecedent these events but the subject's car physically entered the intersection. Furthermore, unintentionally in both of
these intersections a vehicle was crossing the intersection when the subject's car approached the intersection.

- Type C- these intersections include two intersections events (6_3 and 5_4). Meaningful hazard event antecedent these events and the subject's car entered the intersection. It is important to mention that intersection 6_3 happened in the control movie 6 after unplanned event 6_1. However since most subjects mentioned event 6_1 as hazardous it is considered as meaningful hazardous event.

Table 5.1.7.1 summarizes drivers' who responses to these events.

Table 5.1.7.1. Responds to intersections events

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th></th>
<th>B</th>
<th></th>
<th>C</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
<td>NR</td>
<td>R</td>
<td>NR</td>
<td>R</td>
<td>NR</td>
</tr>
<tr>
<td>O</td>
<td>9</td>
<td>23</td>
<td>22</td>
<td>10</td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td>E</td>
<td>11</td>
<td>27</td>
<td>28</td>
<td>10</td>
<td>21</td>
<td>17</td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>41</td>
<td>27</td>
<td>15</td>
<td>18</td>
<td>24</td>
</tr>
</tbody>
</table>

This table presents all drivers who responded to these events (R) and those who didn’t respond to them (NR).

Figure 5.1.7.1 presents the percentage of all drivers who responded to the intersection events from the total drivers of each group both in events from type A and type B.

<table>
<thead>
<tr>
<th>intersection events type</th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>E</td>
<td>28.9%</td>
<td>73.7%</td>
<td>55.3%</td>
</tr>
<tr>
<td>O</td>
<td>28.1%</td>
<td>68.8%</td>
<td>37.5%</td>
</tr>
<tr>
<td>Y</td>
<td>2.4%</td>
<td>64.3%</td>
<td>42.9%</td>
</tr>
</tbody>
</table>

Figure 5.1.7.1. Response to intersection events according to their type.

Figure 5.1.7.1 presents the ratio between the total number of those who responded to the intersection events from each group divided by the total number of drivers in each group of drivers.
The results suggest that in general, the experienced drivers considered intersections as more hazardous than all other groups and young-inexperienced drivers were not different than the old-experienced (O Vs E, \(X_1^2=4.54, P<0.05\); Y Vs O, \(X_1^2=1.55, P<1\); E Vs Y, \(X_1^2=12.34, P<0.001\)). Furthermore, intersections type C where more hazardous than B and B was more hazardous than A that was considered as less hazardous (B Vs C, \(X_1^2=12.3, P<0.001\); B Vs A, \(X_1^2=56.9, P<0.001\)). Detailed analysis revealed that responses to type B and C intersections were not different between drivers (type B: O Vs E, \(X_1^2=0.21, P<1\); Y Vs O, \(X_1^2=0.16, P<1\); E Vs Y, \(X_1^2=0.82, P<1\); type C: O Vs E, \(X_1^2=2.196, P<0.2\); Y Vs O, \(X_1^2=0.21, P<1\); E Vs Y, \(X_1^2=1.22, P<1\)). Type A intersections however, revealed a meaningful difference where old-experienced and experienced drivers where much more sensitive to respond than the young-inexperienced drivers. No difference was found between experienced and old-experienced drivers (O Vs E, \(X_1^2=0.01, P<1\); Y Vs O, \(X_1^2=10.3, P<0.01\); E Vs Y, \(X_1^2=11.04, P<0.001\)).

In summary, all drivers considered intersections as the least hazardous event if a meaningful hazardous event antecedent them and the subject's car did not physically entered the intersection (type A). Experienced drivers however, were more sensitive than all other groups to respond in intersections. Young-inexperienced drivers where less sensitive to respond than all other groups in intersection if a meaningful event antecedent them and the subject's car did not physically entered the intersection (type A).

5.1.7.1 Vehicle crossing an intersection in the control movies

Another interesting phenomenon yet needs more control and validation is that experienced drivers were more sensitive to respond before a crossing vehicle at intersections relative to other drivers. These events included events 6_1 and 2_2.

Table 5.1.7.1.1 summarizes the number of drivers in each group who pressed before and after the vehicle crossing the intersection. "Before" was set to be as the last frame before the crossing vehicle started crossing whereas "After" included all other frames that related to the intersection episode.

Table 5.1.7.1.1. Vehicle crossing the intersection analysis

<table>
<thead>
<tr>
<th></th>
<th>Event 2_2</th>
<th>Event 6_1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>O</td>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>E</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>Y</td>
<td>3</td>
<td>13</td>
</tr>
</tbody>
</table>
Event 2_2 showed that experienced drivers were more sensitive than all other groups to press the button before the vehicle crossed the intersection (O Vs E, $X_1^2 = 6$, $P < 0.025$; Y Vs O, $X_1^2 = 0.02$, $P < 0.025$; E Vs Y, $X_1^2 = 6.45$, $P < 0.025$).

Event 6_1 showed that experienced drivers were more sensitive than the old-experienced drivers to respond before the vehicle crossed the intersection and almost significantly more sensitive than the young-inexperienced drivers (O Vs E, $X_1^2 = 3.95$, $P < 0.05$; Y Vs O, $X_1^2 = 0.74$, $P < 1$; E Vs Y, $X_1^2 = 2.75$, $P < 0.1$).

These intersections episodes couldn’t be analyzed by means of classification type analysis. However, it is important to mention that 6 of the young-inexperienced drivers verbally related to the blue car crossing the intersection in event 6_1 as the hazard instigator and only one old-experienced and one experienced driver mentioned it as the hazard instigator.
5.2 Subject's movies classification

This section analyzes the second phase of the experiment where subjects observed the six hazard perception movies for the second time and in the same order as the first time. At this time they were disconnected from the ETS and they were all instructed once more to observe the hazard perception movies as if they were a driver driving down the road. They were told that at the end of movies' presentation they will be required to classify them into an arbitrary number of groups according to the similarity in their hazardous situations. This procedure resembled the one used by Benda and Hoyos (1983) in which drivers were instructed to do the same procedure with 39 pictures of hazardous driving scenes. Subjects in the current research were then given 6 pictures (one frame from each movie) to help them recall each movie and to enable them to physically pile those six movies into groups.

Analyzing subjects’ classifications began in finding all possible arrangements that were classified by all subjects. All together there were 17 different arrangements (see appendix 10.7.1.1). The first step was to observe all these classifications and try to understand their meaning. This subjective analysis revealed that all possible arrangements might be categorized as to the source of the hazard – human, vehicle, or road - as the following table describes.

Table 5.2.1. Movies categories

<table>
<thead>
<tr>
<th>movies</th>
<th>Hazard Type</th>
<th>Traffic environment characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Planned-in-advance</td>
<td>Unplanned</td>
</tr>
<tr>
<td></td>
<td>Vehicle (Car following)</td>
<td>human</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

The basic attitude towards analyzing subjects' classification was to find association rules that might well describe the nature of all arrangements. The table presents all possible arrangements according two three basic rules.

Hazard Type- hazard type relates to the type of the planned-in-advanced event that appeared in the movie. For example, movies 1 and 5 were similar because they both included a car following and brake of the lead car. Movies 3 and 4 on the other hand included non-driver road users (either bicyclist or a roller blader) crossing the road.
Movies 2 and 6 were similar because they both did not contain planned-in-advanced events. Therefore the possibility to classify these movies together is to relate to hazard type as "None" meaning that in both movies no hazardous situation was identified. This might imply that Hazard type include a sub category of those movies containing planned-in-advance events and movies that contained only unplanned events.

Traffic environment characteristics- Relates to the traffic environment in which the subject's car was driving. Movies 1 and 2 included driving in a two lane road in each direction with relatively open field of view (Urban area) while all other movies included driving in a relatively narrow road with cars parking on two sides of the road (residential area).

One of the experienced drivers was not analyzed because none of his groups were similar to any other classification given by the other subjects in the experiment. Therefore, the analysis included 16 old-experienced, 18 experienced, and 21 young-inexperienced drivers.

Association rules procedure was conducted according to Hand, Mannila, and Smyth (2001) utilizing Clementine software. In order to characterize each driver type it was important to understand all patterns of classifications in the data set. Hand, Mannila, and Smyth (2001) claim that association rules provide a very simple but useful form of rule patterns for data mining. The researchers define a rule as a two sided preposition. The left side is called the "antecedent" or condition and the right side is called the "consequent". Both sides of the equation consist of Boolean statements about the world. The rule states that if the left-hand side is true then the right hand side is also true. Association rules are probabilistic rules and change this definition so that the right-hand side is true with probability P, given that the left-hand side is true. The probability P is simply the conditional probability that the right-hand side is true given that the left-hand side is true.

In the current research there is an interest to find the probability that a certain driver group will classify a group of movies together (e.g. 1, 5). For each drivers group the antecedent (left-hand side) is the number of drivers in each group and the consequent (right-hand side) is the total number of drivers in each group who classified the specific group that was being examined (e.g., movies 1 and 2). Basically the algorithm describes two variables. The first is called the support or frequency and it represents the frequency in which a group of movies has been observed among each driver group. For example, if 9 out of 16 old drivers classified movies 1 and 2 as one group then the frequency of this group would be simply 9/16 that is 56.3%. This value
used to compare between driver groups utilizing an $X^2$ analysis in order to find meaningful differences among groups.

The second variable is called the "confidence". Since the most common groups included two movies grouped together the confidence was calculated only for those common pairs. The confidence that a driver group will classify two movies together (e.g., 1 and 5) is calculated through summarizing all subjects who classified these two movies together by the total number of drivers who classified each of these movies with another movie. Using the previous example if, for example, 3 old-experienced drivers grouped movies 1 and 5 as a group, and the number of old drivers who choused to classify movie 1 with 2 and movie 5 with 6 was 5 then the confidence that an old driver will classify movies 1-5 together given that they both are paired is 3/8 that is 37.5%.

All classifications for each group were divided into three categories: Strong linkage (Support $\geq$50%), Medium linkage (=$\leq$25% support $<50$), and Weak linkage (support$<25$%). For each group, the most interesting linkages were weak (O$<$3 drivers who choused this arrangement, E$<$4, and Y$<$5) drivers or strong (O$\geq$7, E$=8$, and Y$\geq$10). Medium links included the number of all drivers between these pair of thresholds who choused this arrangement. For example, if 9 old drivers thought movies 1 and 2 should grouped than it is a strong linkage since 9 divided by 16 (the total number of old experienced drivers) is grater than 50%. This method showed clearly all meaningful patterns of classifications given by each group of drivers. Both Weak and Strong support are important to characterize each drivers group.

5.2.1 Between and within drivers type classification

The following figures and tables present the summarized analysis including: retrieval cue pictures, links networks, confidence and support, and $X^2$ analysis for all meaningful classifications. Figure 5.2.1.1 present the 6 pictures which aided driver to recollect each of the six movies. Figure 5.2.1.2 presents a link network for each driver type including both medium and strong connections. Table 5.2.1.1 shows how many drivers in each group classified at least one, two, and three pairs of movies that were highly common among some groups and much less in others (High and Low support. Finally, table 5.2.1.2 presents significant and insignificant differences between driver groups relative to each movie group that was examined utilizing $X^2$ analysis.
Figure 5.2.1.1. Movies classification pictures.

Figure 5.2.1.1 presents all pictures that served as retrieval cues for each subject in order to classify the movies into an arbitrary number of groups according to the similarity in their hazardous situations.
Figure 5.2.1.2. Common movies groups' classification.
Figure 5.2.1.2 presents the connection network for each group of drivers. A node represents a specific movie group that was classified by some of the subjects and all lines represent the number of drivers who classified that specific group. A segmented colored line represents a Medium connection (<=25% support<50%) and a black line represents a Strong connection (support>=50%).

The next table presents the most and least common groups that were classified by the subjects. It demonstrates the number of subjects who chose to classify each of these groups the support and the confidence calculations.

Table 5.2.1.1. Number of observations, Support, and Confidence for each group.

<table>
<thead>
<tr>
<th>Movies group</th>
<th>Observations</th>
<th>Support (%)</th>
<th>Confidences (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O  E  Y</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>3 11 17 31</td>
<td>18.8 61.1  81.0</td>
<td>37.5 73.3 89.5</td>
</tr>
<tr>
<td>3-4</td>
<td>9 15 17 41</td>
<td>56.3 83.3  81</td>
<td>100 100 100</td>
</tr>
<tr>
<td>2-6</td>
<td>3 9 13 25</td>
<td>18.8 50  61.9</td>
<td>54.5 50 86.7</td>
</tr>
<tr>
<td>1-2</td>
<td>9 4 2 15</td>
<td>56.3 22.2  9.5</td>
<td>75 36.4 14.3</td>
</tr>
<tr>
<td>5-6</td>
<td>6 4 2 12</td>
<td>37.5 22.2  9.5</td>
<td>66.7 36.4 14.3</td>
</tr>
<tr>
<td>1-5 &amp; 3-4</td>
<td>3 10 15 28</td>
<td>18.8 55.6  71.4</td>
<td></td>
</tr>
<tr>
<td>2-6 &amp; 1-5</td>
<td>3 7 12 22</td>
<td>18.8 38.9  57.1</td>
<td></td>
</tr>
<tr>
<td>3-4 &amp; 2-6</td>
<td>3 7 12 22</td>
<td>18.8 38.9  57.1</td>
<td></td>
</tr>
<tr>
<td>1-2 &amp; 5-6</td>
<td>5 4 2 11</td>
<td>31.3 22.2   9.5</td>
<td></td>
</tr>
<tr>
<td>3-4 &amp; 5-6</td>
<td>5 4 2 11</td>
<td>31.3 22.2   9.5</td>
<td></td>
</tr>
<tr>
<td>1-2 &amp; 3-4 &amp; 5-6</td>
<td>4 4 2 10</td>
<td>25 22.2  9.5</td>
<td></td>
</tr>
<tr>
<td>1-5 &amp; 3-4 &amp; 2-6</td>
<td>3 7 12 22</td>
<td>18.8 38.9  57.1</td>
<td></td>
</tr>
</tbody>
</table>

Table 5.2.1.1 presents first the number of observations in each movie group according to the driver's type. Second, it presents the ratio (support) between those who classified a specific movie together divided by the appropriate population (e.g., 18.8% in the first row represent 3 old-experienced drivers divided by 16 old-experienced drivers). Third, it shows the confidence as previously explained (e.g., 37.5% in the first row represent the probability that if an old driver decided to pair each of movies 1 and 5 he or she will classify them together).

The next table presents the X² analysis summary for most and least common movie groups.
Table 5.2.1.2. $X^2$ analysis' summary according to most meaningful movie groups.

<table>
<thead>
<tr>
<th>Group type and its characteristics</th>
<th>$X^2$</th>
<th>( P_value )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>O $\cap$ E</td>
<td>Y $\cap$ E</td>
</tr>
<tr>
<td>1-5</td>
<td>6.28</td>
<td>1.88</td>
</tr>
<tr>
<td>2-6</td>
<td>3.62</td>
<td>0.56</td>
</tr>
<tr>
<td>1-5 &amp; 3-4</td>
<td>4.86</td>
<td>1.06</td>
</tr>
<tr>
<td>2-6 &amp; 1-5</td>
<td>1.65</td>
<td>1.29</td>
</tr>
<tr>
<td>3-4 &amp; 2-6</td>
<td>1.65</td>
<td>1.29</td>
</tr>
<tr>
<td>1-5 &amp; 3-4 &amp; 2-6</td>
<td>1.65</td>
<td>1.29</td>
</tr>
<tr>
<td>1-2</td>
<td>4.15</td>
<td>1.20</td>
</tr>
<tr>
<td>5-6</td>
<td>0.95</td>
<td>1.20</td>
</tr>
<tr>
<td>1-2 &amp; 5-6</td>
<td>0.35</td>
<td>1.20</td>
</tr>
<tr>
<td>3-4 &amp; 5-6</td>
<td>0.35</td>
<td>1.20</td>
</tr>
<tr>
<td>1-2 &amp; 3-4 &amp; 5-6</td>
<td>0.03</td>
<td>1.20</td>
</tr>
<tr>
<td>3-4</td>
<td>3.00</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Table 5.2.1.2 demonstrates both significant and insignificant differences between drivers' pairwise comparisons. HT includes all classifications in which the Hazards Types were similar. EC includes all classifications in which the traffic Environmental Characteristics was similar. O $\cap$ Y, for example means that old-experienced drivers were compared to young-inexperienced drivers. All $X^2$ analysis has 1 degree of freedom and a confidence level of 95%.

As stated above, at the end of the second presentation of the movies subjects were asked to classify all movies into an arbitrary number of groups according to the similarity in their hazardous situations. Subjects were not told the meaning of “similar” hazardous situations and therefore each subject classified movies together according to his or her subjective perception of similar hazardous situations.

Before describing "Hazard type" and "Traffic environmental characteristics" classifications it is important to mention that some of the old-experienced drivers experienced difficulties in differentiating between movies 5 and 6 and movies 1 and 2 because they didn’t remember the planned-in-advance events described by the retrieval cue and they only recalled the general drive like turning at intersections, give right of way, signaling problems etc. Some experienced drivers also had difficulty differentiating between the movies in the same pairs but they were small. This apparent disadvantage of old drivers will be discussed in details in the Conclusion chapter as it might emphasize the power of the schema by which all frequent episodes such as a braking car are more susceptible to be forgotten (perhaps because they are confused
with other memory traces) than less frequent episodes such as pedestrians jumping into the road. Furthermore, the fact that their titles described details that by no means could have been extracted from the pictures themselves also demonstrates that they forgot specific details which had a higher probability to be forgotten. In general, however, old-experienced drivers gave much less significance to certain planned-in-advance events and therefore they were not taken as classification criterion. Movies 3-4 grouped together (presented in table 4.2.1.2 as "Both") are different from all other pairs since they agree both by means of hazard type (pedestrians) and traffic environmental characteristics (residential area). Therefore observing this group separately (all other groups not paired) is meaningless because it can not differentiate between those who related only to hazard type and those who related to traffic environmental characteristics. All other pairs are similar in only one criterion—either in hazard type or in their environmental conditions and therefore are much more appropriate to this assignment.

5.2.1.1 Hazard type classification

All movie groups' combinations in the first part of table 5.2.1.2 (HT) could only be classified according to the hazard type (planned-in-advance event) that subjects observed in each movie. Groups 1-5 and 2-6 present two pairs of movies that are totally different in their environmental characteristics but similar in their hazard type (planned-in-advance events). Both movies 1 and 2 were filmed in the same urban area. In both movies the road is wide containing two lanes with an open field of view. Movies 5 and 6 on the other hand were both filmed in a residential area. In both movies the road is narrow with parked cars on both sides of the road. Looking at the hazardous events' similarity however reveals that these pairs of movies are similar. Movies 1 and 5 describe situations in which a lead car brakes. Movies 2 and 6 were control movies and therefore didn’t contain any planned-in-advance events. Those drivers who classified these movies together related to the lack of hazardous situations in both movies (they did not contain any planned-in-advance events). As previously mentioned group 3-4 was not interesting to examine as a single group. A combination of group 3-4 with either 1-5 or 2-6 however, enables to determine that the driver related only to the hazard type criterion. Classifying any of the combinations previously mentioned suggests that the subject didn’t relate to the environmental characteristics at all.

Table 5.2.1.2 demonstrates that the old-experienced drivers were less likely than any other group to classify movies according to the hazard type criterion. Specifically, old-experienced drivers were much less sensitive than young-
inexperienced drivers to classify movies according to the similarity in their hazard type in all observed combinations. Comparing old-experienced drivers to the experienced drivers show that they were significantly less sensitive than the experienced drivers in grouping 1-5 alone and grouping 1-5 with 3-4. These drivers were not significantly different in any other combination. Interestingly these drivers were not different in grouping movies 2-6 together where no planned-in-advance event occurred. Experienced drivers were not different from the young-inexperienced drivers in any observed combination.

Interestingly, even if no significant difference was found between the young-inexperienced and experienced drivers when grouping movies 1-5 the experienced drivers tended to titled this group as "keep distance" alluding to the need to maintain safe headways, while the young inexperienced typically mentioned their response like "I had to brake" or described the situation of the braking car "the leading car braked". The complete title analysis will be detailed in section 5.3

In summary, old experienced drivers are the least likely to classify movies according to hazard type criterion whereas young-inexperienced drivers are the most likely to do so. The experienced drivers share some of the old-experienced drivers' characteristics and some of the young-inexperienced drivers' characteristics.

5.2.1.2 Traffic environment characteristics classification

Before describing the second part of table 5.2.1.2 (EC) it is important to mention none of these movie groups' combinations relates solemnly to the traffic environment. There is only one combination that ignores the hazard type criterion completely that is movie 1 and 2 grouped as one group and all other movies grouped as another grouped. No driver in the research was susceptible to classify according to this arrangement. Only three old-experienced drivers did not differentiate movies 3-4-5 (see figure 5.2.1.2) meaning that they gave less importance to whether the hazard was non-driver road users or road users but did differentiate whether there was a hazard or not (3-5 Vs 6 respectively). This connection was not presented in table 5.2.1.2. Hence, all movie groups' combinations relates mainly to the traffic environment characteristics but also give some importance (though less) to the hazard type that was presented in the movie as a classification criterion.

The most important result is that 9/16 old-experienced drivers grouped movies 1-2 as a group. They were significantly different from the 4/18 experienced and 2/21 young-inexperienced drivers who also grouped these movies together. This means that old-experienced drivers gave much sensitive to whether the environment was urban or
residential. Given that movies shared the same environmental characteristics they then distinguished between the planned-in-advance events. Events that were not perceived as exceptional dangerous (like pedestrians) such as car following were more likely to be forgotten or disregarded in some cases and were not taken as classification criterion. They gave much more importance to the general attributes of the environment (e.g., intersections, parked cars, the field of view, the width of the road, etc.) and that is consistent with Endsley's (1995) and Benda and Hoyos's (1983) claim that experienced operators have a holistic perception of the environment.

Interestingly, the 1-2 & 3-4 & 5-6 arrangement was the only one that repeated among all groups when traffic environmental characteristics criterion was being examined. Specifically, 4 old-experienced, 4 experienced, and only 2 young-inexperienced drivers choused to classify the movies accordingly. All drivers who choused to classify this arrangement related to the environment physical attributes but also differentiate pedestrians from only vehicles hazardous situations. Since grouping 5-6 together was only significantly different between the young-inexperienced and old-experienced drivers suggest that similarly to previous results the experienced drivers gave more importance to the environment characteristics than the young-inexperienced drivers.

In summary, old-experienced drivers were highly sensitive to the general attributes of the environment and least sensitive to specific hazardous planned-in-advance events (Hazard Type) especially when no pedestrians were involved. The young-inexperienced drivers were less likely to classify according to the general environmental characteristics and most likely to relate to the materialized hazardous events (hazard type criterion). The experienced drivers shared some attributes of the old-experienced drivers and some of the young-inexperienced drivers. It seems that the more experienced is the driver he or she pays more attention to general details and potential hazards that the environment may produce. Lacking past experience the materialized hazards captures most of the driver's knowledge base and awareness and the level of hazardousness is set accordingly. This means that all other immaterialized hazards become much less important.
5.3 Subjects' titles for classified movies subsets

The final step of the experiment was to title each group of movies classified earlier with a caption that best describes it. This procedure resembled Benda and Hoyos’s (1983) procedure in which subjects were asked to classify 39 pictures of hazards situations into an arbitrary number of groups of pictures similar in their hazardous situations and then title each group. In their experiment Benda and Hoyos (1983) found that drivers with more experience (drove almost twice as many km as the other group) rank ordered their groups according to their perceived level of hazardousness (“This is most… least hazardous group” etc.), while inexperienced drivers classified the situations, using a nominal scale, into groups based on the environmental situation ("The situations in this group are similarly hazardous because of the intersections in each", "all wet road situations", etc). Furthermore, the researchers mentioned that the novice drivers related to unimportant details that were ignored by more experienced drivers.

In this study I found that most old-experienced and some experienced drivers tended to classify movies according to traffic environmental general attributes and less to the specific hazardous situations that they actually saw. That implies that these drivers created a holistic representation of the environment by ignoring occasional situations and relating to typical environmental characteristics such as urban or residential areas that may produce different hazardous situation. It was also important to examine whether a group of movies received the same titles by all drivers groups. This analysis was interesting to examine whether different types of drivers- who grouped the movies similarly - gave different titles. It was expected that the more experienced drivers would categorize according to the level of danger (more…least hazardous) and crate a holistic representation of the environment while the novice will only relate to the type of danger being observed and pay more attention to unimportant details which all group of drivers actually saw. If so, it might agree with both Endsley's (1995) claim and Benda and Hoyos's (1983) findings.

The most common arrangement included groups 1-5 & 2-6 & 3-4. This classification was extremely common within the experienced and young drivers (57.14% of the young and inexperienced drivers and 38.89% of the experienced drivers) but less common in the older population (18.75%). Some experienced drivers titled this arrangement of movies groups as more…less….and least hazardous situations whereas most young-inexperienced only titled according to the planned-in-advance events (e.g.
movies 1 and 5 are similar because they both included a braking car). This result matches some of Benda and Hoyos’s (1983) results and conclusions.

Moreover, movies 1 and 5 could be differentiated according to subjects’ titles. In both of these movies the dangerous planned-in-advance situation included a sudden braking of a leading car but titles were different between the driver groups. Previous results have demonstrated that this arrangement was highly common among young-inexperienced drivers (17/21) and experienced drivers (11/18) and much less among old-experienced drivers (3/16) who only classified movies 1 and 5 as a group as part of the 1-5, 3-4 and 2-6 arrangement. Therefore, it would be highly interesting to examine differences between the young-inexperienced and experienced drivers.

All titles were given to seven different referees (The questionnaire can be found at appendix 10.8.2). This procedure was aimed to examine whether my assumptions regarding these titles are unbiased and therefore correlates with external referees statements who were not involved in the research. The research hypothesis was that the titles for movies 1 and 5 given by experienced drivers would describe this group in terms of preventive actions that might prevent these kinds of hazardous situations. For example, "keep your distance from the leading car" could prevent an accident and will give the tailgating driver enough time to respond in case the leading car brakes. The novice drivers however, lacked the knowledge base of what kind of actions the leading car might do, like braking. Therefore, this group was highly surprised when the car braked and titled the same group from a response point of view; i.e., in terms of actions they had taken in response to the leading car action. For example, "I had to stop immediately when the leading car brake lights turned on".

In order to examine this hypothesis all titles were classified according to my decision and then titles were presented to seven different referees for classification. Each referee was given a verbal description for both movies 1 and 5. Then, he or she were told that the list of titles which they need to classify were given by subjects as titles for these two movies that they thought were similar in their hazardous situations. Each referee was instructed to decide whether the title characterized a driver that responds to events, or to the actions needed to prevent events or the title is too ambiguous for classification. All referees were drivers with an average driving experience of 13.3 years. In order to examine the level of agreement between all seven referees A Kappa (Cohen) analysis was used (further reading of the statistical method can be found in Byrt et al 1993; Cohen, 1960). The analysis revealed a high agreement between referees with Kappa (Cohen) = 0.775 and P <0.001.
The complete list of all referee's statements regarding each title that was given by the subjects are presented in appendix 10.8.2. Titles, that repeated more than once (few subjects gave the same title) were presented only once for classification decision.

The next table includes only few typical titles where the level of agreement among referees was high, one title given by an old driver and all "problematic" titles in which level of agreement was low. The table also includes an additional column presenting the type of the driver who gave the title. This column was not shown to any of the referees.

Table 5.3.1 Titles for movies group 1-5.

<table>
<thead>
<tr>
<th>Serial num</th>
<th>Title</th>
<th>Driver type</th>
<th>Number of referees</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Prev-ent</td>
</tr>
<tr>
<td>1</td>
<td>Danger from the car in front- keep distance</td>
<td>E</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>No signal</td>
<td>O</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>Car brakes</td>
<td>Y</td>
<td>0</td>
</tr>
<tr>
<td>7</td>
<td>Unexpected actions of surrounding vehicles</td>
<td>Y</td>
<td>1</td>
</tr>
<tr>
<td>9</td>
<td>Car in front of me- must pay attention to brakes, turns etc.</td>
<td>Y</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>A danger resulted from another car</td>
<td>Y</td>
<td>0</td>
</tr>
<tr>
<td>17</td>
<td>Emergency brake</td>
<td>Y</td>
<td>0</td>
</tr>
<tr>
<td>18</td>
<td>Medium danger</td>
<td>E</td>
<td>1</td>
</tr>
<tr>
<td>22</td>
<td>Danger resulting from other vehicles that drive the same road. In order to prevent must keep distance</td>
<td>E</td>
<td>7</td>
</tr>
<tr>
<td>25</td>
<td>Risks resulting from other cars emerging in traffic</td>
<td>E</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5.3.1 presents only few titles from all titles given by subjects in the experiment. As previously mentioned the experienced and young-inexperienced drivers were much more likely to classify these movies together than the old-experienced drivers. All "keep distance" combinations were observed only among experienced drivers population. "No signal" was stated only once by an old-experienced driver and all "braking car" combinations were used mostly by the young-inexperienced population (one experienced driver and one old-experienced driver also related to the braking car in front). Titles marked in yellow represent low level of agreement.

Results show that the most common title given by the young-inexperienced drivers to movie group 1-5 related to the action that the car in front did or to the action they had to take in order to avoid a possible accident. The experienced driver related
mostly to actions he or she should take in order to prevent similar future situations. Though the percent of old-experienced drivers who classified these movies together was low relatively to the other groups (O-18.8%, E-61.6%, Y-81%) it was interesting to see that one of the three drivers who grouped movies 1-5 mentioned also a preventive act – "No signal" that might have prevented the hazardous situation. This title resembles the reasons given previously by the old-experienced drivers when they mentioned the cause for pressing the button in the previous paragraph. Titles 9, 10, 18 and 25 are more problematic because no agreement was observed. It is important to mention that all referees were experienced drivers with average of 13.3 years driving the roads.

Title 9 was distributed equally between a preventive and a responding driver (only 1 referee couldn't classify this title). Those referees who classified the driver as a preventive related to the last part of the title where the driver mentioned the "Must pay attention" while those referees who classified the driver has a responding one related to "Car in front of me" description in the beginning of the title. The fact that all referees were experienced drivers biased their assessment when they read the “must pay attention” part by thinking what it meant for them. The inexperienced drivers however were only paying attention to the current situation and "paying attention" is meaningless retrospective statement since they didn't predict the lead’s car sudden action.

Title 18 is very interesting because it represents, as previously mentioned, a rank order among all groups that weren't presented to referees. The driver who titled movies 1 and 5 as a medium risk titled movies 3 and 4 as the most dangerous and movies 2 an 6 as low danger. This rank order resembles Benda and Hoyos's (1983) results that were previously discussed. No young-inexperienced drivers classified these groups in a rank up order of their danger.
6 Discussion

The current research examined how experience and age affect the ability to perceive hazards in the traffic environment. Three driver groups took part in the research including young-inexperienced, experienced, and old-experienced drivers. The results presented in the previous chapter demonstrated differences in visual search patterns, sensitivity to hazards, and classification criterion between experienced or old-experienced drivers and young-inexperienced drivers. This chapter discusses each part of the results separately, and then in general. The chapter ends with a discussion about future research and some of the current research limitations.

It will be argued that the young-inexperienced driver could be seen as one who responds to events rather than anticipate them. This driver understands and implements the meaning of a dangerous situation only when he or she is personally required to take an action in order to avoid an obstacle (either dynamic or static) that will result in a collision otherwise and may harm either the driver or other road users. The experienced driver prevents dangerous situations from happening by detecting potential hazards and taking necessary actions. He or she is satisfied in finding the hazard and is confident in the maneuver he or she should take. The old experienced driver prevents a danger through detecting potential hazards, drives slowly by default and less confident in his or hers responses and is not willing to be surprised.

6.1 Performance on the specific dependent measures

6.1.1 Subjects button presses: reactions to hazards

Subjects in the current experiment were asked to observe six movies of different traffic situations from a driver's perspective and to press a button as soon as they perceive a hazardous situation. Subjects were given a definition for hazard as presented in the method chapter, and half the subjects in each group were also given a further explanation regarding hazardous situation based on Surrey's, 1974, model. This explanation suggests that before an accident occurs there are primary consecutive events and attention to them might prevent an accident. This procedure was meant to examine whether young-inexperienced drivers might benefit from increasing their awareness for cues prior to the occurrence of a dangerous situation. The results showed that explicitly instructing the young-inexperienced driver to pay attention to cues that might indicate
an upcoming danger was useless since these drivers lacked the relevant past experience and appropriate knowledge base (Logan, 1985) to decipher such cues.

The result chapter examined three aspects of the button presses: reaction time, response sensitivity, and classification type analysis. All these measures clearly demonstrated age and skill differences in the ability to perceive hazards while driving. This part summarizes the conclusions that are relevant to each of these aspects. The first paragraph discusses the general events analysis and the second is more event specific.

6.1.1.1 General events analysis

The results demonstrated, as expected that movies 2 and 6 were considered less dangerous than all other movies. In both of these movies there were no planned-in-advance materialized hazards. These results might imply that all drivers were indeed affected by all planned-in-advance events. Two highly important findings revealed that first, old-experienced and experienced drivers were more sensitive than young-inexperienced drivers to immaterialized events which appeared after the planned events. These results are consistent with Underwood et al.’s (2005) findings that older and more experienced drivers generally responded more often than younger-inexperienced ones; as if they detected hazardous situations that could not been detected by novices. Specific events that included intersections and a pedestrian walking on the curb have created the meaningful difference between experienced (either old or not) and young-inexperienced drivers. It seems that both experienced and old-experienced drivers detect potential hazards. Experienced and old-experienced drivers have learned to match a specific materialized hazard with a specific action based on scripts from long term memory. In the absence of a clear hazard they are afraid of potentially dangerous situations since they are not sure which script they may use or because they are aware of possible deleterious outcomes which these events may produce. Young-inexperienced drivers lack the appropriate knowledge base (Logan, 1985) of possible deleterious outcomes and therefore they are less sensitive to intersections and pedestrians walking on the curb since they hardly ever experienced dangerous outcomes that such events may produce (e.g., the children will suddenly cross the road). Second, the intersection analysis revealed that in general all drivers were less likely to respond in intersections if a meaningful hazardous event preceded them. This is interesting since it might imply that all drivers set the hazard severity according to the most hazardous event and all other events were set accordingly. This means that until a meaningful hazard occurred, all subjects considered intersections threatening, but after a hazardous event the intersections appeared less threatening. Young-inexperienced drivers however, were
least likely to respond in intersections if a meaningful hazard preceded them and the distance between their car and the intersection was relatively large. This result strengthens the previous conclusion that they are less aware of the potential danger that intersections pose. Their lack of knowledge is reflected by the fact that in the absents of past experience their hazard perception is set only through events they currently observe. When a meaningful hazardous event occurs they are more susceptible than experienced drivers to drastically change their hazard perception accordingly. All other immaterialized hazards become much less hazardous than those meaningful hazards.

6.1.1.2 Specific events' analysis

This paragraph discusses the results according to specific events and their characteristics. The most significant results from all events are summarized and presented in the next table.

Table 6.1.1.2.1: Reaction time, Response sensitivity and Classification type analysis.

<table>
<thead>
<tr>
<th>Hazard type</th>
<th>Cue characteristics</th>
<th>support</th>
<th>Reaction time</th>
<th>Response sensitivity</th>
<th>Classification type analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car following</td>
<td>Residential-close distance (5_2)</td>
<td>HS</td>
<td>Y=O=E</td>
<td>Y=O=E</td>
<td>O=Car emerged from the right E/Y=brake of the lead car</td>
</tr>
<tr>
<td></td>
<td>Urban-far distance (1_3)</td>
<td>HS</td>
<td>O&gt;E/Y, Y=E</td>
<td>Y=O=E</td>
<td>O=No signaling of the lead car E/Y=brake of the lead car</td>
</tr>
<tr>
<td>Pedestrians</td>
<td>On the road in front (4_1, 4_2 and 4_3)</td>
<td>HS</td>
<td>Y=O=E</td>
<td>Y=O=E</td>
<td>O/E/Y= Hazard identification</td>
</tr>
<tr>
<td></td>
<td>On the road in front (3_1)</td>
<td>LS</td>
<td>Y=O=E</td>
<td></td>
<td>Y/O/E= Old woman</td>
</tr>
<tr>
<td></td>
<td>Right curb (3_2, 4_4*)</td>
<td>LS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intersections</td>
<td>Type A (1_4, 3_4)</td>
<td>LS</td>
<td>O/E&gt;Y</td>
<td>O=E</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type B (6_1, 2_2)</td>
<td>HS</td>
<td>O&gt;E</td>
<td>O=Y</td>
<td>Y=O=E</td>
</tr>
<tr>
<td></td>
<td>Type C (5_4*, 6_3)</td>
<td>HS</td>
<td>O&gt;E</td>
<td>O=Y</td>
<td>Y=O=E</td>
</tr>
</tbody>
</table>

Table 6.1.1.2.1 summarizes the reaction time, response sensitivity and classification type analysis results. Cells in gray represent events that were not measured with that specific measure. The cue characteristics relate to the environmental conditions in which the event occurred. "Support" presents whether the event had high support (HS) or low support (LS) either if it was planned or unplanned-in-advance. All other headers represent all measures that were analyzed. O=old experienced, E= experienced and
Y=young-inexperienced. Y=O=E means that there was no different among groups. O>Y, for example in the reaction time measurement means that the O where slower than Y to respond. O>Y, for example, in the response sensitivity means that O were more sensitive than Y to respond. For type A, B, and C intersection explanation see paragraph 5.1.7.

* In event 4_4 the experienced drivers were not different from the young-inexperienced drivers to respond (P<0.2) but the trend was similar. No young-inexperienced verbally mentioned the children walking on the curb and none pressed the button. Two experienced driver pressed the button and one mentioned their detection verbally. Event 5_4 revealed no significant difference in reaction time between drivers.

Table 6.1.1.2.1 suggests that when the hazard was meaningful and included pedestrians all subjects were equally sensitive to respond (press the button), there were no differences in reaction times (the frame number in which the button press was recorded), and their verbal descriptions (subject verbally mentioned the hazard instigator for each event) were similar. Chapman and Underwood (1998) have shown that novice and experienced drivers were equally sensitive to events that were planned by the researchers as hazardous situations. The current results are consistent with theirs. When the danger was imminent and salient all drivers reacted at the same time in order to avoid the danger. Pedestrians are most vulnerable and probably less predictable than other hazards, and therefore all drivers thought that these events were dangerous at the same time.

Car following however, revealed some differences between drivers although all drivers were equally sensitive to respond to these two events. When the environmental characteristics included a residential area, all drivers were equally sensitive to the lead car’s braking. When the environmental conditions included an urban area with a relatively wide road and a long distance to the lead car old-drivers were slower to respond. It is reasonable to assume that old-experienced drivers thought that they have more time to respond since the distance between them and the lead car was relatively big. Assuming that these drivers usually drive slowly by default they were less interested to indicate that they were braking but were more interested to know why the lead car suddenly brake. In the residential area however, the distance to the lead car was much shorter and therefore they had to respond quickly.

Intersections type B- that were not preceded by a meaningful hazardous event but in which the subject's car physically entered the intersection, produced reaction time difference between the old-experienced who were slower to respond and the experienced drivers. No significant difference was found between the old-experienced
and the young-inexperienced nor between the experienced and the young-inexperienced drivers. Although the difference was not significant, the experienced responded first to these intersections. The experienced drivers also mentioned the intersection as hazardous earlier since they recognized the hazard and the need to slow down. This result is similar to the car following event in the urban area. In all of these cases old-experienced drivers were slower to respond. It seems that since they are aware of their limitations they are more careful and drives slowly. Unless they are surprised, from pedestrians for example, they are less afraid since they have more time to respond.

Lastly, some of the planned-in-advance events (3_2 and 3_3; 4_1 and 4_2; 5_2 and 5_3) were divided into two separate events since some drivers pressed twice—once to indicate the hazard identification and the second was when the dangerous situation occurred. Separating the events was highly common among young-inexperienced and old-experienced but less among experienced drivers who pressed only at the beginning of the event. In all these pairs of events the hazard instigator remained in the scene. It seems that the experienced driver is satisfied only in finding the hazard instigator. Once it is detected he or she is no longer afraid and is confident in the maneuver he or she should take. They are confident because they count on their previous knowledge and performance in similar situations. Young-inexperienced drivers pressed twice since they were unaware of how the hazard might evolve once it was detected. Therefore, when the hazard materialized they were surprised and pressed twice. These conclusions are consistent with Armsby et al. (1989) and Bragg and Fin. (1986) findings that experienced drivers rated potentially dangerous situations such as fog or tailgating more dangerous than novice drivers but rated pedestrians crossing the road less hazardous than the inexperienced drivers. Events 3_2 and 3_3 were different because in this pair no young-inexperienced driver responded while the roller blader was still on the curb (they saw him according to the eye movements' analysis). Old-experienced drivers always pressed twice (also in events 3_2/3_3). They always detected the hazard prior to its materialization but also when it was materialized. It appears that these drivers recognize all potentially hazardous situations, think they are hazardous but since they are aware of their limitations they are more afraid when the hazard materializes and they indicate that by pressing the button again.

6.1.2 Eye movement analysis

During the first movies’ observation all subjects were connected to the ETS and eye samples were recorded on each frame. Running the movie as sequence of single frames enabled an accurate analysis of eye samples per frame. Endsley (1995) claimed
that novice and experience operator might notice the same elements within the environment but only the experienced operator will be able to integrate these elements to create a holistic representation of the environment. Endsley (1995b) however, mentioned that eye movement analysis is not an appropriate measure to quantify SA at a specific point in time. Wickens (2001) claimed however, that looking at eye movements might teach us about the process of maintaining SA. Analyzing fixations have demonstrated how the schema directs the experienced driver’s eyes to specific locations were the most important information is located but also to the process of maintaining SA at car following or approaching intersections episodes.

6.1.2.1 General eye movements' analysis

In accordance to Chapman and Underwood (1998), fixations duration was much shorter in residential areas (movies 3-6) relative to urban areas (movies 1-2). It seems that when the information within the environment increase, subjects divide their attention between more objects at the same time unlike urban relatively open roads in which they can dedicate more time to each object.

6.1.2.2 Events specific eye movements' analysis

This paragraph discusses the results according to specific events and their characteristics. The most significant results from all events are summarized and presented in the next table.

Table 6.1.2.2 Eye movements' results summary

<table>
<thead>
<tr>
<th>Hazard type</th>
<th>Cue characteristics</th>
<th>Horizontal fixation location</th>
<th>Regions of Interest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car following</td>
<td>Urban (1_3). The lead car was at the center of the road</td>
<td>O=E= between parked car on the right and the lead car. Y=Lead car</td>
<td></td>
</tr>
<tr>
<td>pedestrians</td>
<td>On the road in front (3_3)</td>
<td></td>
<td>O/E/Y= detect</td>
</tr>
<tr>
<td></td>
<td>Right curb (3_2, 4_4)</td>
<td></td>
<td>O/E/Y= detect</td>
</tr>
<tr>
<td>Intersections</td>
<td>Type A (3_4)</td>
<td>O=E= Right side of the right &quot;T&quot; intersection(├) Y= Center of the intersection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>5_2*</td>
<td>O=E= Right side of the right &quot;T&quot; intersection(├) Y= Center of the intersection</td>
<td></td>
</tr>
</tbody>
</table>

Table 6.1.2.2 summarizes eye movements’ results. Cells in gray represent events that were not measured in that specific measure. The cue characteristics relate to the environmental conditions in which the event occurred. Horizontal fixation location relates only to horizontal fixation location analysis and Region of Interest relates only to events where ROI’s were defined and examined whether or not subjects fixated inside them. All events had low support.
* Event 5_2 occurred when a third car emerged from the right and the lead car had to brake. This event is considered an intersection event only in the eye movements' analysis few frames prior the entrance of the third car to the intersection.

Pedestrians were highly interesting based on the eye movements, while they were still on the curb. These events were considered as least hazardous by the young inexperienced drivers and therefore it was interesting to examine whether young-inexperienced drivers detected them while they were on the curb. According to the eye movement analysis all drivers (regardless the group type) fixated and noticed the pedestrians when they were on the curb. This means that young-inexperienced drivers didn’t think they were posing any threat. These findings strengthen previous results and emphasize the inability of young inexperienced drivers to perceive potential hazards. They lack the knowledge and past experience and they are not familiar with environmental constraints (e.g. the roller blader might jump into the road if he doesn’t have enough space on the curb). These results are consistent with Endsley’s (1995) claim that novice and experienced operator may notice the same elements (SA-level 1) but novice may fail to integrate those elements into a holistic representation of the environment (SA-level 1) and predict near future events (SA-level 3).

The car following episode in movie 1 revealed that old-experienced and young-inexperienced drivers tended to direct their gaze between the lead car and the parked car on the right. Young-inexperienced drivers directed their gaze toward the center of the lead car. These findings may explain why more experienced drivers can detect more accidental events (Underwood et al., 2005). These drivers are more aware of the potential hazards that parked car may produce on the one hand and they are less afraid of the lead car when and if its driver decides to brake. The young-inexperienced drivers are unaware to potential hazards and therefore most of them direct their gaze towards the most conspicuous object which attracts their attention.

Right "T" intersections (├) events revealed that the more experienced drivers direct their gaze towards the right side where a side road emerges while young-inexperienced were more likely to look straight forward and neglect the road on the right side. The more experienced drivers where directed by their predetermined schema and directed their gaze towards locations hazards have high probability to appear. Event 5_2 indeed showed that both old-experienced and experienced drivers directed their gaze toward the right side of the intersection several frames before the entry of the third car from the right.
6.2 Movies classification and titles

The second and third part of the research was designed according to Benda and Hoyos’ (1983) procedure. Subjects observed all six movies the second time and in the same order as the first (only without measuring eye movements). Subjects were instructed once more to observe these movies as if they were a driver driving a road and then to subjectively classify all six movies into an arbitrary number of groups according to the similarity in their hazardous situation. This procedure was a bit different from that in Benda and Hoyos’ (1983) research because in their research the subjects were not supposed to recall any information when they observed the pictures. In this research movie’s classification was based on recalling each movie episodes according to the pictures that used as retrieval cues.

Results were extremely interesting since they revealed a totally different attitude between the groups of drivers when classifying the movies. Two extremely important factors were found to influence the movies’ classification criterion. The first is the hazard type and the second that was much more meaningful among the old-experienced drivers is the general attributes of the environment. Old-experienced drivers were more likely to classify movies according to the similarity in the general traffic environment attributes (urban versus residential areas), whereas young-inexperienced drivers were much more likely to classify all movies according to the similarity in the materialized hazards (planned-in-advance events). Experienced drivers who had approximately 30 years less driving experience than the old-experienced drivers demonstrated some characteristics similar to the old-experienced drivers but also to the young-inexperienced drivers. All drivers however, gave some importance to the materialized hazards especially when pedestrians burst into the road. It is argued that the relevance of both of these factors improves with experience but when subjects are requested to classify movies according to the similarity in their hazardous situations the second factor is more salient in distinguishing between experienced (especially old-experienced) drivers and young-inexperienced drivers.

The hazard type factor reflects the subjective estimation regarding the possible consequences of the event. For example, both young-inexperienced drivers and experienced drivers classified pedestrians as more dangerous than car following rear-end events. This might suggest that since pedestrians are less protected the consequences might be much more deleterious than if the event includes only vehicles. Furthermore, three old-experienced drivers classified the movies according to the
hazard type factor and most old-experienced drivers classified movies 3-4 that included pedestrians as hazardous. Furthermore, this group of movies was not analyzed by means of titles because all drivers mentioned that, pedestrians jumping into the road are dangerous. According to Matthews and Moran (1986), two factors influence the driving actions: Risk utility and risk perception. The risk (hazard) perception receives feedback from the driving actions through driving experience while the risk utility takes into consideration other driver characteristics such as declarative knowledge about the world and personal characteristics. Young-inexperienced drivers who lack the experience are more susceptible to decide whether to act according to the risk utility factor. The more experienced is the driver the more he or she responds to events and gives more weight to the hazard perception. Experienced drivers learn to estimate the level of hazardousness according to their subjective experience. Most drivers were rarely involved in harmful accidents and therefore might perceive hazards as less dangerous if the number of past episodes ended without any deleterious outcomes. This factor was not strong enough to reveal any difference between the young-inexperienced drivers and the experienced drivers because young-inexperienced drivers who had no meaningful past experience were equally sensitive to classify movies 3-4, 1-5, and 2-6 into groups as the experienced drivers. The fact that the risk perception affects the driver's decision whether to respond or not implies that this factor's effect is more salient when drivers actually responds to events. Indeed experienced drivers were much more sensitive to respond to potential hazards that occurred after the planned-in-advance events than the young-inexperienced drivers. This means that the sensitivity threshold whether to respond or not is highly dependent on the number of past episodes in which the driver had to respond in order to avoid an accident. The more episodes the driver experience the more he or she knows how to operate and therefore they are less afraid than young-inexperienced drivers when it occurs. With the lack of past experience young-inexperience drivers were much more susceptible to set the level of hazardousness according to the observed materialized hazards and less on past episodes.

Responding to event also enables the experienced drivers to predict an upcoming danger and to respond even if the hazard has not materialized. Moreover, previous results revealed that the experienced drivers were more afraid from a potential hazard than from materialized hazard. These findings are consistent with Bragg and Fin (1986) and Armsby et al. (1989) findings that experienced drivers classified traffic scenes pictures less hazardous than young-inexperienced when they included pedestrians walking along the road whereas they classified pictures of fog and tailgating more
hazardous than young-inexperienced drivers. It was suggested that the more similar episodes a driver experience with no deleterious outcomes the more he or she perceive the event as less hazardous. This might imply that the frequency of a specific hazard affects the perceived level of hazardousness. Traffic environment that produces more hazardous events are perceived as more hazardous than environment with less frequent hazardous events.

The frequency of a specific hazard is highly dependent on the environmental general attributes (e.g., pedestrians are more likely to appear in residential areas than in highways). To get familiar with such frequencies may be regarded as understanding the environmental constraints (Vicente and Wang, 1998). This factor's impact was highly salient in the movies classification assignment. The old-experienced drivers were most likely to classify the movies according to the general attributes of the environment (e.g., narrow Vs wide roads, intersections, parked cars, turning, etc). Even if hazardous situations are not frequent enough to be automatically processed (Haworth et al., 2000), old experienced drivers considered car braking much less hazardous than pedestrians. These drivers experienced difficulties in differentiating between control and non control movies if the only hazard was rear-end event. The fact that some of these drivers had difficulties in elaborating the planned-in-advance event when it was a rear-end episode might imply that their vast array of memory traces and could not differentiate between the new episode and all past events. Furthermore, the fact that old-experienced drivers tended to group rear-end events and control movies in urban areas more than in residential areas might imply that rear-end episodes are more common in urban areas than in residential areas. General environmental attributes like intersections, parked cars and physical road characteristics are imbedded in more memory traces than a vast array of hazards. Specific environmental attributes however produce typical hazards. Even if the driver does not know exactly which hazard might appear he or she knows that some hazard may appear. The more experienced the driver, the more he or she learns to estimate these frequencies. Old-experienced drivers were probably the most sensitive to these frequencies and created holistic representation of the environment (Endsley, 1995, Benda and Hoyos, 1983) by classifying the movies according to similar environmental attributes.

Eye movements’ analysis revealed that experienced drivers tended to gaze towards the right side of intersections where a road emerges and towards parked cars on the right. This might imply that even if experienced drivers can not tell which hazard may appear they know were a hazard is most probable to appear. As Endsley (1995)
claimed, novices are helpless seekers of information within the environment. More experienced drivers operate according to their predetermined schema that allows them to integrate elements within the environment and predict potential hazards.

### 6.3 Conclusions and summary

In summary, it seems that two meaningful factors impact hazard perception: The perceived hazard frequency and the perceived severity possible outcome that such hazard may produce. Both of these factors improve with experience. The more a driver responds to events and experience driving the more he or she estimates properly the probabilities that hazards might appear in specific environments and subjectively assess the possible outcomes that such hazard may produce based on past experience. The level of hazardousness each driver possesses is a combination of these two factors. With the lack of experience the risk utility plays a key roll in assessing the level of hazardousness in a situation. Experience enables driver to integrate elements in the environment and predict future events (Endsley, 1995).

Young-inexperienced drivers may be therefore seen as those who respond to events while experienced drivers prevent them. An elegant example from the research results have shown that though experienced and young-inexperienced drivers classified movies 1-5 together young-inexperienced drivers titled the group as "I had to suddenly brake" or "The lead car suddenly braked", and the experienced drivers alluded that they should have kept a larger headway.

The main question resulting from the current research is whether hazard perception movies can replace the realistic experience of driving and improve young-inexperienced drivers' hazard perception without jeopardizing other drivers.

### 6.4 Research limitations and future research

The current research results and conclusions are interesting since they demonstrate age and skill differences in driving related hazard perception. The current research however examined only six hazard perception movies which didn’t represent all road types and did not include a vast array of hazards. In order to establish a theory it would be necessary to film much more hazard perception movies that will include more hazardous situations and a variety of traffic environments.

The most interesting question that this research raises is whether movies of hazard perception improve young-inexperienced drivers' perception of hazards which may lead to less young-inexperienced drivers' accident involvement. In order to examine this question the array of hazard perception must be large and must include more hazardous
situations and much more diverse. Furthermore, the future research should include more participants, especially young-inexperienced drivers. In order to examine whether movies improve hazard perception the future research must include a control group of young-inexperienced drivers that will not observe the movies. Positive results may promote the idea of using hazard perception movies to teach inexperienced drivers to identify hazards before driving and to reduce their accidents involvement resulting from perception errors.

The current research suggests that two meaningful factors impact hazard perception. The research however lacked the ability to examine which factor is more influential. Old-experienced driver who classified movies according to the general attributes when no pedestrians appeared in the scene might have classified one of the urban scenes as equally hazardous to a residential area if it contained a pedestrian. If so that means that the severity of the incident impacts more than the frequency. Future research can add episodes in which pedestrians crossing a fast road. It is important to mention however that a pedestrian crossing a wide urban road is much less frequent than in residential area.

One of the research assumptions is that old-experienced drivers where highly sensitive to potential hazardous situations but they were also aware to their limitation and therefore drives slowly by default.

Old-experienced drivers had generally longer mean fixation durations than all other groups. Maltz and Shinar (1999) have demonstrated that old drivers had longer searching episodes but no evidence for longer mean fixations duration. It can be postulated that older drivers may need more fixation time in order to process information. One difference between Maltz and Shinar's research is the dynamic environment Vs static environment. In static environment (in their research they have shown a traffic scene picture) subjects have time to return to previously seen locations but do not have that time in dynamic environments. In order to examine whether older drivers needs more time to process information and compare a static environment a dynamic a much more control research should be conducted.

Technology and time limitations prevented the use of Hart Rate Variability (HRV) to measure stress on drivers once they recognize a hazard. Future research might include a more sophisticated technology to enable the synchronization between these two measures. Using these systems together may give a more holistic description of drivers’ performance when they detect hazards. One of the implications of HRV might examine where young-inexperienced drivers are more surprise when a hazard materialized.
7 Policy recommendations

The research main purpose was to find those factors that construct hazard perception and how these factors are affected by driving experience. Though this is only a basic research the evidence suggest that the factors which were found to be highly connected to hazard perception are mostly dependent on driving experience and that they are trainable. Therefore, the study establishes a platform for future research which will examine whether training young-inexperienced drivers in these factors off the road will improve their hazard perception capabilities. Improving young-inexperienced drivers' hazard perception capabilities off the road may reduce road accidents and save lives.

8 References


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