

# “COGNITIVE ACTIVITY MODELLING: A CASE STUDY OF LANE CHANGE SCHEMAS AND SENSATION SEEKING”

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**Abstract:** We propose a method to investigate differences of driving at a tactical level, between different categories of drivers. We analysed the naturalistic driving performance of 19 French drivers using an instrumented vehicle. We assessed their sensation seeking scores with the Zuckerman questionnaire. We observed a significant correlation between their sensation seeking score and their mean speed on motorway. We set up a method to model their tactical behaviour and investigate possible correlation between their sensation seeking score and their tendency to perform certain types of behaviour. We applied it to the study of lane changes on motorways. We could model two categories of lane changes but we show that they were not correlated with the sensation seeking score. Despite this negative first result, we are proposing an innovative approach for this kind of study.

## 1. Introduction

Sensation seeking is a personality trait defined by the seeking of varied, novel, complex, and intense sensations and experiences and the willingness to take physical, social, legal and financial risks for the sake of such experiences [1]. The driving environment is an everyday situation which allows sensation seekers to exhibit typical sensation seeking behaviours. The automobile can provide a variety of intense experiences including; speeding, racing other cars, reckless overtaking [2]. High sensation seekers are more likely to have accidents and receive traffic citations [3, 4] and are significantly more likely to report aggressive driving habits [4].

The habits and preferences of high sensation seekers (HSS) are aimed at maintaining an optimal high level of arousal. Driving is a significant means of achieving this. It is reasonable to assume that accident and speeding ticket prone young drivers are more likely to be high sensation seekers, scoring high on scales that measure attitudes towards speeding and harbouring self-serving attitudes and erroneous beliefs congruent with their higher preferred levels of arousal [5, 6, and 7]. [8] indicated that high sensation seekers were significantly more likely than low sensation seekers to speed, not wear seat belts, drink frequently, drive after drinking, perceive a low risk of detection for impaired driving and perceive that they could drink more beer after being impaired. [9] illustrates that those individuals who score highly on scales which measure sensation seeking are also more likely to commit traffic violations, are more impulsive and are less likely to use their safety belts.

It is apparent that there are substantial differences in the driving behaviour observed in high and low sensation seekers. Questions remain however regarding the differences in the cognitive processes that govern the behaviour of sensation seekers and how these differences can be identified? In an attempt to answer this question we apply the ABSTRACT

cognitive modelling approach to data collected using the instrumented vehicle. Firstly we aim to establish that the sample we have selected is representative of sensation seeking behaviour by correlating behaviours that typify the sensation seeker (average speed, maximum speed and Time-To-Collision) with participant's scores on the general sensation seeking scale. We then used the ABSTRACT methodology to develop a case study comparison to investigate the driving performance of high and low sensation seekers in order to establish differences in cognitive schemas between high and low sensation seekers.

The cognitive modeling of an operator is based on the fundamental notion that they do not act according to the objective status of the world but according to a "mental model" or "representation" that they make of it. Cognitive models are usually constructed by cognitive psychologists or ergonomists. They rely on concepts such as "schemas", "Scripts" [10], "Scenarios", "Operative Image" [11], or "Situation Awareness" [12]. The latter offers a covering notion by simultaneously addressing the perception, the comprehension and the anticipation for describing how the elements of the situation are "mentally" taken into account by the operators.

The question of knowing which data must be selected to describe "the meaningful (to the subject) aspects of its activity" is a crucial question when one builds cognitive models. Answers to this question can come from both an analysis of the activity and from cognitive theories. To address this question we have developed a method and a tool named Abstract which is described below. This method is based on the collection of behavioral data from driving with an instrumented car. And the transformation of this data to a higher level description of the activity focusing on what is held as being meaningful to the driver. We can so highlight significant patterns of behavior that were actually performed by the subject during the experiment. These patterns can be taken as mental schemas of the activity. It is reasonable to assess that these mental schemas will depend on the subject's personality. This is this assumption that we would like to investigate here.

## **2. Method**

### **2.1 Participants**

19 (9 male, 10 female) participants were selected at random from an opportunity sample of French drivers. All participants held a French Category B driving license and had normal to corrected vision. The Category B licence permits a driver to drive a vehicle with a maximum weight of 3.5 tons, and seating no more than 9 passengers, including the driver. This includes standard passenger cars, people carriers and minibuses. The average age of participants was 33 years old (range 25 to 55) and they had held a Class B licence for an average of 13 years (range 2 to 39). They reported an average annual mileage of 12,364 miles per year (range 2,000 to 50,000). Participants received a standard payment of €80 for taking part in this study.

### **2.2 Instrumented Vehicle**

The experiment is run using an instrumented vehicle which is a Renault Scenic. It has a two liter, 16 valve engine. It is fitted with four video cameras that record front view, rear view, side mirrors and the driver and two roof top mounted cameras for obstacle detection. There are a further two cameras linked to an 'Eyetracker' system that are responsible for detecting the 'zone of interest' towards which the driver has directed their gaze.



**Figure 1:** The LESCOT instrumented vehicle.

It is fitted with a Navteq ADASRP global positioning system (GPS) that is used to compare the recorded data points with the video output. There are four computers located in the rear storage compartment; 1 Pentium III, 1 GHz, P.C. dedicated to collecting vehicle parameters (pedals, steering wheel, speed, acceleration, etc.); 1 Pentium IV 3 GHz dedicated to collecting FaceLab data (gaze detection, direction, etc.); 1 dual Pentium III 1.6 GHz dedicated to obstacle detection and 1 Pentium M 1.6 GHz dedicated to GPS information. It has one point telemeter (LMS) located on the front right of the vehicle and one scanner telemeter (SICK) in front of the car at the centre that works in conjunction with two cameras located on the roof of the vehicle for obstacle detection. The algorithm used in the detection system was developed by INRETS-LIVIC during the ARCOS project (2004). It is equipped with sensors on each pedal, the steering wheel, the indicator and headlights [13].

## **2.3 The course**

The course of the experiment is 50 km long and includes urban, suburban and motorway sections. The urban and suburban sections include numerous junctions, roundabouts and traffic lights. Participants are required to navigate a number of different road types ranging from small roads to large motorways. This study is primarily concerned with data collected during the motorway section. During the whole course there is a significant interaction with other road users.

## **2.4 Zuckerman's Sensation Seeking Scale Form V (SSS)**

The Sensation Seeking Scale [1] is composed of 40 dichotomous forced choice questions. The forced choice paradigm requires participants to choose the option that most reflects their behaviour. A score of one is given if the sensation seeking option is selected. A score of zero is assigned if the alternative option is chosen. The total score is generated by calculating the number of sensation seeking responses. This scoring system is consistent with other applications of the sensation seeking scale.

Within the general sensation seeking scale there are four contributing factors [14, 15]. Each of these sub-scales is represented by ten questions on the SSS. The dimensions of sensation seeking explored by the SSS are; Thrill and adventure seeking (TAS; Contains questions relating to the participants' attraction to thrill, dread and particularly a willingness to engage in physically risky activities or extreme sports like parachuting, mountaineering and skiing); Experience seeking (ES; Contains questions relating to participants aspirations to

undergo a variety of novel experiences through the mind and senses, especially arousing music, art, travel, social non-conformity and the association with fringes of conventional society); Disinhibition (Dis; Contains questions which relate to participants loss of self control and sensation seeking through social activities e.g. drinking, parties, sex) and Boredom Susceptibility (BS; which refers to their intolerance toward monotonous, repetitious or predictable people and events).

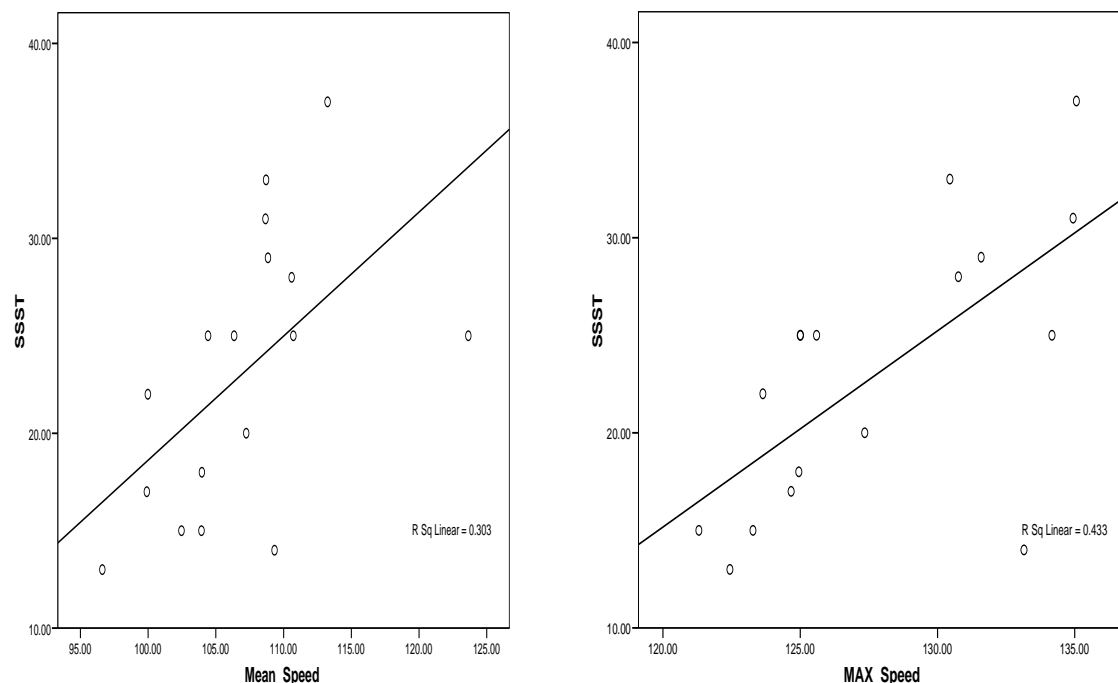
## 2.5 Method of behavioural data analysis

For the behavioural data analysis, we have used a methodology and a tool developed at Inrets, called Abstract (Analysis of Behaviour and Situation for menTal Representation Assessment and Cognitive acTivity modeling) [16, 17]. It allows us to translate the data collected from sensors in the instrumented vehicle into a higher level of description. This higher level of description highlights patterns of behaviour that can be explained by the fact that the drivers carries out cognitive schemas. These cognitive schemas are shaping the know-how and the reasoning performed by the driver.

## 3. Results and Discussion

The first aim of this study was to analyse the behaviour of participants to ensure that it was consistent with that described in the sensation seeking literature. A key indicator of sensation seeking behaviour in the driving task is speed. In this instance both the average speed and maximum speed were significantly correlated with total sensation seeking score. The presence of this trend in the data is evidence that the sample selected is representative of sensation seekers in general.

**Figure 2:** Correlation of SS total score with mean and maximum speed



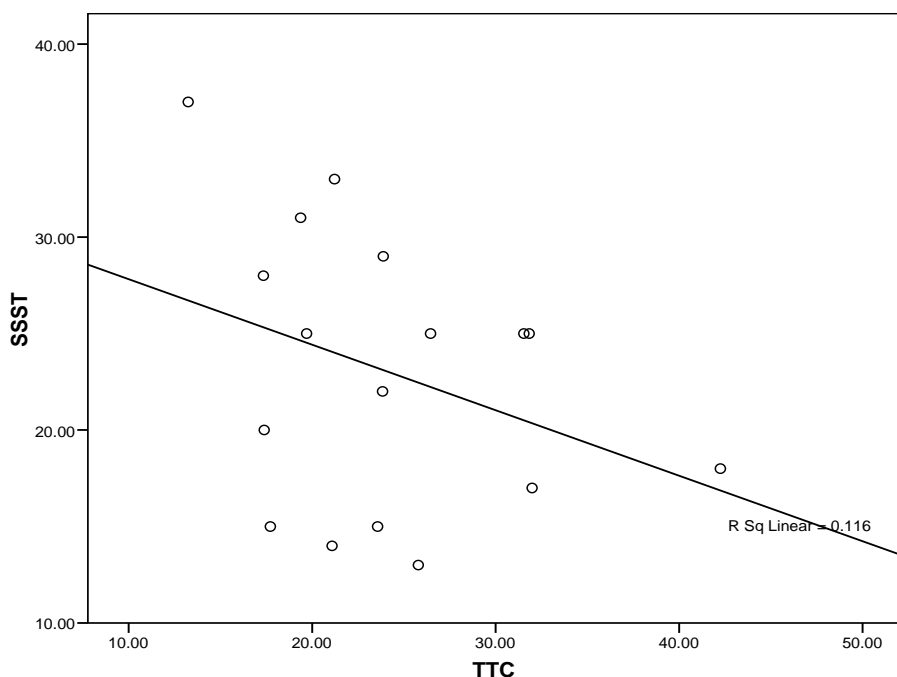
There is a significant correlation between sensation seeking total score and mean speed ( $r(17) = .550, p < .05$ ). This is illustrated in Figure 2 which shows that as sensation seeking total score increases so does the mean speed travelled in the instrumented vehicle. A similar trend is observed between total sensation seeking scores and the maximum speed travelled

in the instrumented vehicle. Figure 2 shows that there is an increase in maximum speed as total sensation seeking score increases. This is supported by the statistical analysis of this trend (a significant correlation between sensation seeking total score and maximum speed ( $r(17) = .658, p < .01$ ).

A further variable that has been associated with sensation seeking is headway (measured using time-to-collision; TTC); in this instance headway was measured by the forward telemeters. A decline in TTC as shown in figure seven is suggestive of a decrease in the headways maintained by participants scoring high on sensation seeking and although the results of a statistical analysis indicate that the relationship between sensation seeking total scores and TTC is not significant ( $r(17) = -.341, p > .05$ ) the fact that this is approaching significance is reassuring given the context of data collection. It is possible that there is variability in the TTC measure due to inconsistencies in traffic flow. Differing traffic flow is a key issue in terms of the reliability of results as there are few controls that can limit the impact of this variable. In this study the time of day at which the experiment took place was controlled in the hope that peak traffic flow would be consistent for that particular time, however this does not take into account the impact of school and national holidays, commuters, weekend traffic or other factors that may impact the number of road users during any particular trial.

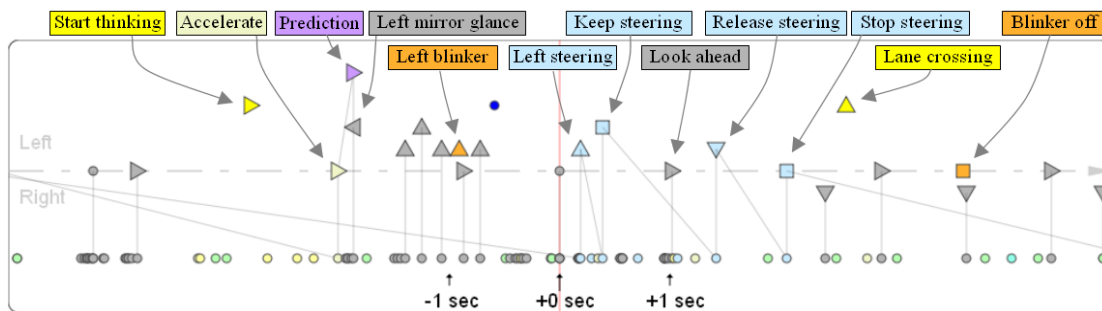
The weather conditions at the time of the trial can have an impact on the data collection. Rain or overcast conditions can affect the efficiency of the telemeters that measure headway. It can also interfere with the clarity of the video recordings provided by the in car cameras. Sunshine can also cause problems with data collection as glare can affect the output of the video recording equipment and can also impact on the accuracy of the eye-tracking data due to reflective glare and the 'squinting' of participants. The negative elements of using a naturalistic driving scenario are negated by the rich data that can be collected. When using an ecologically valid experimental paradigm we can be assured that the behaviour observed is realistic.

**Figure 3:** Correlation of sensation seeking total score with time to collision



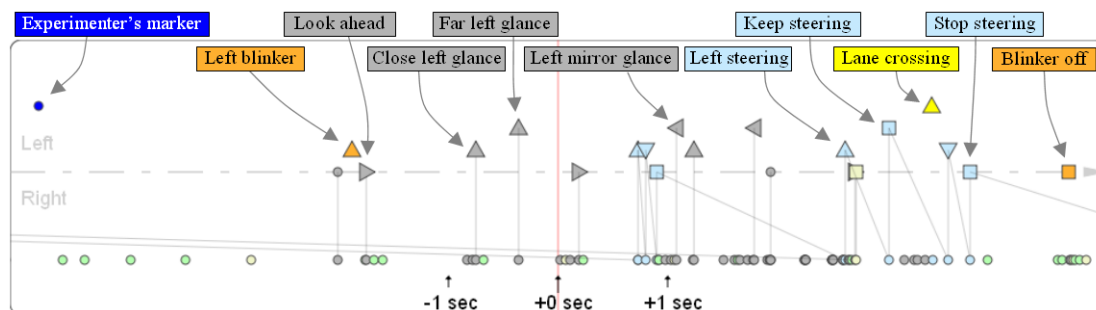
### 3.1 Lane change schema

We have focussed our study of tactical behaviour on lane change manoeuvres. We have chosen this type of manoeuvre because it is ubiquitous in the driving environment [18]. It combines many critical features of driving including control, monitoring and decision making. A lane change is defined as a more or less stable sequence of actions that begins with the motivation to change lanes i.e. in the presence of a slow leading vehicle, followed by a gathering of information about the surrounding traffic situation and then the decision whether to change lanes or not. The analysis with Abstract let us [18] identify the two categories of lane change schemas that are explained below.



**Figure 4:** Lane\_Change\_Accelerate

Figure 4 shows a lane change with acceleration. In this situation the driver is impeded by a vehicle slower than his desired speed. He may check his left mirror several times, then, when he decides to overtake, he accelerates while checking his mirror; he switches his blinker on, starts steering, and crosses the line.



**Figure 5:** Lane\_Change\_Stable\_Speed

Conversely figure 5 illustrates a lane change where speed is stable, in this situation, the overtaking is done "on the fly" with no speed variation. The blinker is switched on with a good anticipation before the checking to the left mirror and the beginning of the manoeuvre.

Can we therefore, identify differences in the steps (cognitive schema) taken by high and low sensation seekers in a specific driving behaviour (overtaking)? We aimed to do this by identifying differences between frequencies of lane changes by participants with divergent sensation seeking scores. Every participant performs both Lane\_Change\_Stable\_Speed and Lane\_Change\_Accelerate lane changes, but we could formulate the assumption that high sensation seekers would perform more Lane\_Change\_Accelerate, because they may have a more dynamic driving style.

However, the relationship between SS-Total and total number of lane changes was not significant, nor did we find evidence to confirm our hypothesis that sensation seekers would perform more lane changes with acceleration than stable lane changes. The lack of a significant relationship between sensation seeking and lane changes is discouraging.

However, these schemas were not made with the intention to describe typical low or high sensation seeking patterns of behaviour. We attempted to correlate schema previously defined by [18]. A future direction for this research may involve the analysis of driving behaviour in which participants are pre-selected in terms of their sensation seeking scores. The ABSTRACT methodology could also allow us to model behaviour from the point of view of Sensation Seeking by focussing on indicators that we think may highlight differences with regard to sensation seeking, such as the strength of acceleration or steering.

There are further improvements that could be made to this methodology that may increase the likelihood that we achieve the hypothesised results, they are to increase the sample size and use a simulated driving task. With a larger sample of participants we can increase the power and accuracy of the parameters that we are measuring [19]. It will reduce the variability of measures which will in turn yield more sensitive hypothesis tests with greater statistical power and smaller confidence intervals. Additionally replication of this experiment in a driving simulator may give us greater control of the experimental context. As suggested in the discussion of the relationship between sensation seeking and TTC the differences in road environment (e.g. traffic flow) may impair our ability to record accurate data. The application of the ABSTRACT methodology in an advanced driving simulator would allow strict control of the driving environment while maintaining the ecological validity of the task. In its current form (instrumented vehicle trial) the Data can be noisy, meaning that the patterns identified are meaningless. Simulation would allow us to replicate the exact traffic flow conditions for each participant so that they are effectively performing the same lane change at the same time which would allow us to better compare the differences.

Given the lack of evidence to support our hypothesis we may have to conclude that sensation seeking is not an important influence on driver's lane change behaviour. However we believe that we have applied a novel approach to sensation seeking using an innovative methodology and that with further development we may be able to disseminate a relationship between sensation seeking and lane change behaviour.

## 5. References

- [1] Zuckerman, M. "Dimensions of sensation seeking", 1971, J Consult. Clin. Psychol. 36: pp. 45-52.
- [2] Arnett, J.J., Offer, D. and Fine, M.A.: Reckless driving in adolescence: 'state' and 'trait' factors. *Accid. Anal. & Prev.*, 1997, 29(1), pp. 57-63.
- [3] Furnham, A. and Saip, J.: Personality correlates of convicted drivers, *Pers. and Ind. Diffs.*, 1993, 14(2), pp. 329-336.
- [4] Heino, A., van der Molen, H.H. and Wilde, G.J.S.: Differences in risk experience between sensation avoiders and sensation seekers, *Pers. and Ind. Diffs.*, 1996, 20(1), pp.
- [5] Arnett, J.: Heavy metal music and reckless behaviour among adolescents, *J Youth and Adol.*, 1991, 20(6), pp. 573-592
- [6] Clement, R. and Jonah, B.A.: Field dependence, sensation seeking and driving behaviour. *Pers. and Ind. Diffs.*, 1984, 5 (1), pp. 87-93.
- [7] Whissell, R.W. and Bigelow, B.J.: The speeding attitude scale and the role of sensation seeking in profiling young driver at risk. *Risk Analysis*, 2003, 23(4), pp. 811- 820.
- [8] Jonah, B., Thiessen, R. and Au Yueng, E.: Sensation seeking, risky driving and behavioural adaption, *Acci. Anal. and Prev.*, 2001, 33(5), pp. 679-684

- [9] Wilson, R.J.: The relationship of seat-belt non-use to personality, lifestyle and driving record. *Health Education Research*, 1990, 5(2), pp. 175-185
- [10] Schank, R. C. and Abelson, R. P.: *Scripts, plans, goals and understanding*. Hillsdale, N.J., 1977.
- [11] Ochanine, V. A.: *Concept of operative image in engineering and general psychology. Engineering Psychology*. B. F. Lomov, V. F. Rubakhin and V. F. Venda. Moscow, Science Publisher
- [12] Endsley, M. R.: "Toward a theory of situation awareness in dynamic systems." *Human Factors*, 1995, 37(1): pp. 32-64.
- [13] Labayrade, R., and Aubert, D.: A single framework for vehicle roll, pitch, yaw estimation and obstacles detection by stereovision. *IEEE Intelligent Vehicle Symposium 2003*, Columbus, USA, 2003, pp. 9-11.
- [14] Zuckerman, M., Eysenck, S.B.G., and Eysenck, H.J.: Sensation seeking in England and America: cross-cultural, age and sex comparisons. *J of Cons. and Clin. Psych.*, 1978, 46, pp. 139-149.
- [15] Rowland, G.L., and Franken, R.E.: The four dimensions of sensation seeking: a confirmatory factor analysis. *Pers. and Ind. Diff.*, 1986, 7(2), pp. 237-240.
- [16] Georgeon, O., A. Mille, and Bellet, T.: *Analyzing behavioural data for refining cognitive models of operator. Philosophies and Methodologies for Knowledge Discovery*, Krakow, Poland, IEEE Computer Society Press Proceedings, 2006.
- [17] Georgeon, O., Henning, M.J., Bellet, T. and Mille, A.: *Creating cognitive models from activity analysis: a knowledge engineering approach to car driver modelling*. International Conference on Cognitive Modeling. Ann Arbor, MI, 2007.
- [18] Henning, M. J., Georgeon, O. & Krems, J.: The quality of behavioural and environmental indicators used to infer the intention to change lanes. *4th International Driving Symposium on Human Factors in Driver Assessment*. Stevenson, Washington USA, 2007.
- [19] Ajgaonkar, S.G.P.: The effect of increasing sample size on the precision of an estimator. *The Amer. Stat.*, 1967, 21(24), pp. 26-28.