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Towards a Formal Representation of Cognitive Dissonance Knowledge Application: Control Driving Vehicles

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Abstract - This paper presents an approach based on the notion of Object Knowledge (OK) to facilitate the cognition dissonance diagnosis. This approach is enhanced with a Metaknowledge system (Driver-Vehicle-Environment) which will be modeled with objects knowledge and specified by a temporal formal language. We will first present the concept and theory of dissonance and the strategies to reduce it. Then, the approach is tested for controlling driving vehicles. Finally, the paper shows the use of cognitive dissonance diagnosis in real time system.

Key-Words: Cognitive dissonance, inconsistency, behavior, attitudes, temporal logic, dissonance reduction, diagnostic, Metacognitions, Objects Knowledge

I. INTRODUCTION

Different concepts, theories and ideas have enriched the literature on in diagnosing the behavior of car drivers over time. The theory of cognitive dissonance is a new concept and proves to be of great relevance for the study of the diagnostic [1]. It is based on the car drivers' behavior [2]. In this study, we will introduce the concept of cognitive dissonance in a simplified form. We will also introduce the features and ways to overcome the dissonance in making decisions during risky situations.

The theory of cognitive dissonance is a theory to avoid the inconsistency [3]. This theory shows if the two cognitive elements (propositional attitudes and / or behaviors) are related or not. Thus, the dissonance is integrated in the diagnosis process to predict the state of the drivers.

According to Leon Festinger [3], cognitive dissonance exists when the driver's behavior is in conflict with his knowledge or belief.

In social psychology, the theory of cognitive dissonance indicates that individuals have an incentive to reduce dissonance by changing existing cognitions. Further he can add new cognitions to create a coherent system of beliefs, or he can reduce the importance of one of the dissonant elements [4].

Festinger defined cognition as "knowledge, opinions or beliefs about the environment, on oneself or on his own behavior". Thus, the driver's gaze, the use of rear-view mirrors, the acceleration / deceleration of the car are examples of cognitions.

Relations between cognitions must be qualified as consistent if one implies the other, or inconsistent (or dissonance) if one implies the opposite of the other [3].

1.1 Types of cognitions

a. Consonant or coherent cognitions

Cognitive elements are in harmony when they coexist harmoniously within the cognitive system, and are logically derived from each other [3]. For instance, "When the stop sign shows up, the vehicle driver must stop" (cognition 1). "The driver presses on the brakes to decrease the speed" (cognition 2).

b. Dissonant or incoherent cognitions

Conversely, in the case of dissonant cognitions, cognitive elements do not coexist harmoniously within the cognitive system [3]. They do not derive logically from each other, and sometimes clash. An example is given in Fig.1, "at a stop sign, the vehicle driver must stop" (cognition 2). "The driver keeps up the speed of his car and does not stop" (cognition 1).

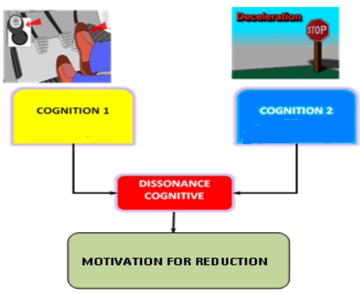

Fig.1 : Dissonance Cognition

1.2 Dissonance reduction strategies

In the presence of dissonance in any situation, such as driving, (the attitudes and behavior of the driver are not consistent), the driver can be in a bad condition. This phenomenon explains the need to implement dissonance reduction strategies. These strategies are based on the following approaches [5]:

a. Cognitive change

Cognitive dissonance can be reduced or eliminated while adding new cognitions that build consonant elements. Therefore it would decrease the proportion of cognitive elements that are dissonant. Under this perspective, the driver does not change his behavior but only the perception of it or meaning he gives.

b. Behavior change

Following the troublesome behavior the driver tries to perform a second behavior. In this mode of reduction (adding a consistent behavior), the driver acts in a way so that attitudes and behaviors are consonant.

II. DIAGNOSIS APPROACH BASED ON COGNITIVE DISSONANCE

The model in Fig.2 shows the different components involved in the diagnosis of dissonance. The two basic components of this model are the knowledge base and the Metacognition.

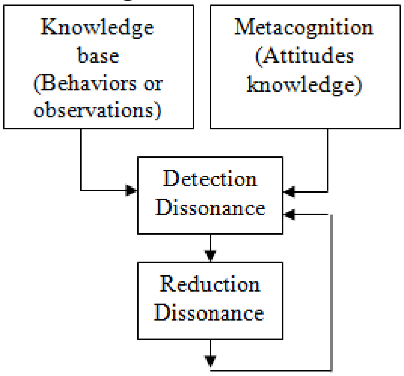

Fig.2: Structure model of cognitive dissonance

a. Knowledge base

This base gathers knowledge related to observations (behavior) of an individual in a particular context (for instance in the car driving context, the individual is the driver).

Driving process requires the acquisition of complex cognitive skills. This is knowledge about the properties of cognitive functioning of the driver and on the changes of links between the system elements (vehicle, driver, road environment). The essential of Metacognitive knowledge concerns actually the combinations of two or three of these categories, or interactions between them. Any relative lack of this knowledge weakens the proper use of cognitive processes.

Today, there are several technologies, entirely independent of the driving system. Many of them are already integrated into a vehicle, such as satellite navigation and digital maps enables the driver to learn about the car's position. Other facilities enables him to have a 360 degrees view around the car in all conditions. Also, we found in vehicle the sensors that can communicate with other vehicles or parts of road infrastructure such as traffic lights, pavements. Others serve to know the features of their local environment (behavior of nearby cars), detect pedestrians crossing the road, perceive the surrounding traffic, detect traffic signs, etc.

Our knowledge base (Fig.3) comprise of multiple sources. These sources of information come from embedded systems in vehicles, and from a variety of sensors including long and short term radar, cameras and ultrasonic distance sensors to detect lane markings and GPS data. Consider some examples of data that can be obtained by the driver-vehicle-road environment system.

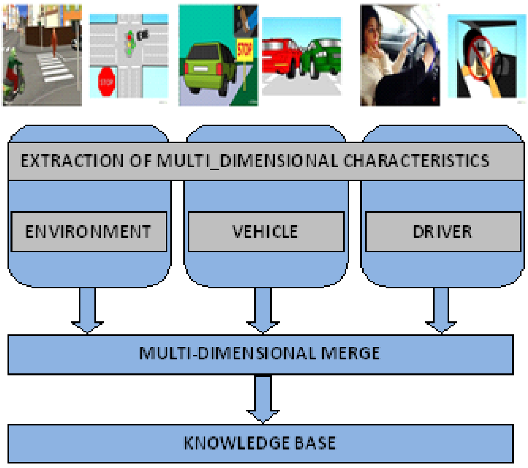

Fig.3: Multi-sources knowledge base

Data coming from the road environment:

The primary requirement of the driving activity is to monitor the external environment. This requirement helps to adjust with the changes in that environment. It also helps to avoid any obstacle or pedestrian who could arise in the path of driving. Road signage is to ensure the safety of road users (such as vehicle drivers, cyclists and pedestrians), and improve the efficiency of the movement of vehicles on the roadway. It contains:

- Traffic signs, light signals, pavement markings.
- The weather, the road state (ice, icy surface, etc.)

Data coming from vehicle:

- The detection of the vehicle location on the road
- The changes of the lateral position of the vehicle, lane change
- The detection of variations in the steering wheel
- Detection of the lane departure using a monitoring system which is at the front of the car
- The vehicle speed

Data related to driver behavior:

In addition to information that the driver collects from the road environment, and from the vehicle state, the driver determines the instructions (control actions). These instructions can be applied on the vehicles to carry out the driving task by mainly using visual information. Other information comes from sensors that perceive the driving state and detect various aspects of driver. Those aspects comprise of driver's fatigue, the waking state, the position of the hands, the gaze direction of the eyes (open or closed), detection of the head movement, the position and the angle of the head.

The most popular measures in the research are:

- The hand position (driving), feet position (pedal)
- The head position,
- Fatigue, stress, crippled, pupillary change followed by the gaze direction,

b. Metacognition:

It is defined as "knowledge of knowledge" [6]. It refers to knowledge of the subject (e.g. car driving) regarding his own cognitive processes and products It also refers to the active control, regulation and orchestration of these processes.

This knowledge base includes laws, rules and regulations. It provides information on laws, rules and regulations that all drivers should know for practicing secure driving.

Knowledge Metacognition concerns the knowledge attitudes described by three types of knowledge: declarative, procedural and conditional [6] (Fig.4).

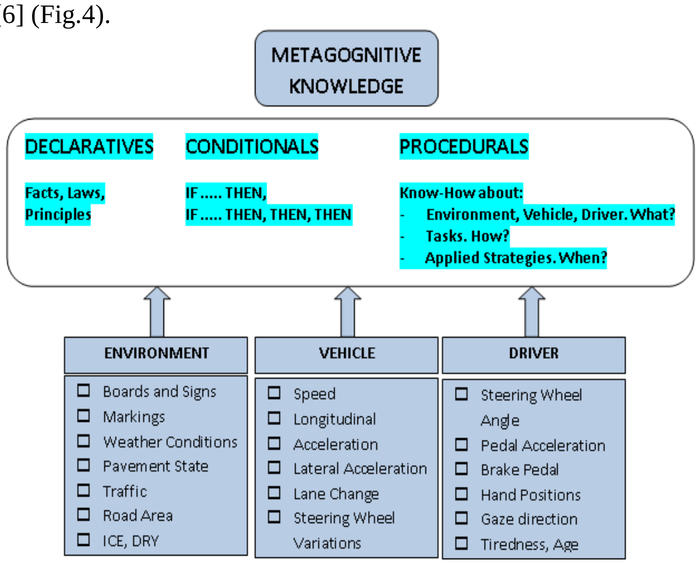

Fig.4: Metacognitive Knowledge Model

Declarative knowledge: Declarative knowledge is factual knowledge. It corresponds to theoretical knowledge recognized by a community of practice at a given time. It is often expressed in the form of rules and is actualized in the knowledge of the individual. Example, "What to do before a stop sign? The driver must completely stop his car for a period of 10s. "

Procedural knowledge: this knowledge generally correspond to the expertise, this is actualized in action sequences and answer the question: "How to do? "Example, progressively reduce the speed of the car before arriving at the stop sign".

Conditional knowledge: It relates to the actions' conditions. Without this knowledge, declarative knowledge remains inert and those procedural cannot be activated. The constraints associated to these actions are temporal type. So, the notion of time must be specified in the evaluation of each of the given type of knowledge. This concept of time will be used for the specification of temporal properties using a formal specification language. We quote the linear temporal logic LTL or Timed Computation Tree Logic TCTL.

The TCTL allows modeling the timed behaviors of real-time systems or refers sometimes to quantitative temporal logics [7]. It models the time, while keeping the quality aspect, which therefore will determine the effective duration of a state or determine the time that separates a state from another.

c. Dissonance detection

The detection is to search the dissonance arising from the comparison between the behavior of the individual and the expected attitude [8]. For instance, "in front of a stop sign, the vehicle driver must stop" (attitude), "The driver keeps the speed of his car" (behavior). We search the dissonance which is necessarily linked to the interactions between the various components of the system (driver-vehicle-environment road). This dissonance results in a detachment between what is observed and the requirements of laws and assumptions related to the mode of road driving [9].
The diagnostic process is described by the following steps:

- Acquire the current observations of the vehicle, driver and environment.
- Identify the suitable attitudes related to the current situation.
- Compare observations to attitudes.

When there is a dissonance, apply the most suitable dissonance reduction strategy.

d. Dissonance Reduction

Once a dissonance is detected under this model, then it is used to apply the most appropriate method of reducing the dissonance. According to the applied reduction strategy, the dissonance is reduced by the behavior change or attitude change.
The dissonance detection and reduction operate in closed loop until the disappearance of dissonance.

III. FORMAL REPRESENTATION OF OBJECTS KNOWLEDGE

The term Object Knowledge designated by OK is an approach allows (by defining the structure of an object) the representation of the static and dynamic aspects of knowledge. The object can be an instance of a domain class or an instance of a relationship between several domain classes. We denote E the set of domain classes and Ci a domain class: E = {C1, C2, C3, ...,Ck}.

A domain or context Cn is seen as a set of interacting processes where each one operates on a set of object knowledge OKs. Among these OKs, there are those that are found at the beginning of the process evolution called Pre-Object Knowledge (PreOK), others that come at the end of the process evolution called Post- Knowledge Object (PostOK) (Fig.5).

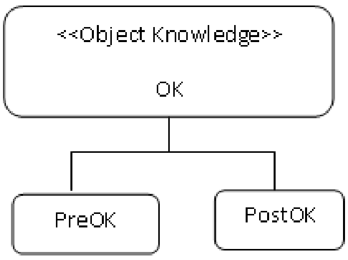

Fig.5 : Graphic representation of OKs

A process model based on the notion of object knowledge is schematically represented as (Fig.6):

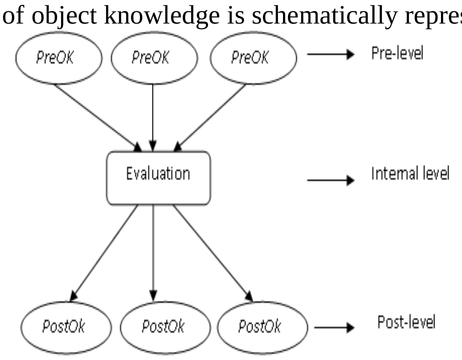

Fig.6: Object Knowledge Based Process (OKBP)

An instance of OKBP model is a process operating on cooperative OKs (PreOK) and having as objectives to achieve the object knowledge PostOK. The (PreOK) will be considered as previous events that will allow us to have a good events prediction index. For instance, while a driver is driving a car, the event such as "braking of a vehicle" typically follows the event "appearance of stop sign". The event "Put the foot (right) on the pedal brake" often precedes the event "Vehicle deceleration".

In our approach, each object is associated with a time interval which is characterized as a non-zero length of time in seconds. This time duration of object knowledge PreOK is denoted OKLT (Object Knowledge LifeTime). This duration is less than or equal to the process lifetime (PLT) (OKLT<= PLT).

Thus, we can summarize, a context Cn is described by an objective O, a set of domain classes E and a set of process P. We denote Cn = {O, E, P} with P = {P1, P2, P3, ... ,Pn}, E = {C1, C2, C3, ..., Ck}. With, O is the objective of context Cn. So, it is the conjunction of all objectives of all processes related to Cn. It may be denoted as O = O1^ O2 ^O3 ^ ...... ^On, with Oi as an objective reached by a process Pi. The objective Oi of Pi process can be formally represented as PostOK1 ^ PostOK2^ ..... ^PostOKn. Finally, a process Pi of a context Cn operates over a set of object knowledge OK1, OK2, etc. Pi (OK1, OK2, ...,OKn) with pi Є P.

Object knowledge "OK" is an instance of a domain class or a relationship between the domain classes of E denoted R. We denote R = C1 x C2 x ... .Cn.

An object knowledge OK has a priority index represented by a non-zero positive integer. Hence, we denote Pi = {(OK1, integer1) (OK2, integer2) (OK3, integer3), ..., (OKn, integern)}. This integer can be used to interpret the priority knowledge okj. Note that the lowest integer value represents the highest priority.

An object knowledge OKj, of a process Pi defined in a context Cn, is described by strategic, declarative and procedural properties forming a tuple:

Okj = {Cn, Pi, R, type, psg, pdc, ppr} with:

Cn: Context,

Pi: process,

R: relationship between domain classes,

Type: indicates the knowledge level of 'OKj' in the process (pre or post)

psg: a set of strategic properties temporal and conditional (described with TCTL language)

pdc: a set of declarative properties (properties here represent the static aspect of an object knowledge).

ppr: a set of procedural properties (events and / or actions). We specify the properties using the timed computing tree logic (TCTL) where some properties are represented as function of time.

Therefore, between the present and future there is a multitude of possible sequences.

pds: Dissonance reduction properties. Two forms of properties behavioral and attitudes.

To illustrate these concepts, let's take an example:

Strategic Properties psg:

- **Conditional properties:** The driver must start deceleration after detecting a stop sign (from a distance <= 150 m or 10.8 s). We define in the logic TCTL the properties vmvt: vehicle in movement; vdec: vehicle in deceleration. The formula AGφ means in TCTL that the property φ is always true. The formula AFφ means that φ is inevitable which means that φ becomes true one day.

AG(vmvt ∧ AppStop Sign → AF ≤10.8s vdec).

- **Timed properties:** The vehicle will be immobilized for at least one unit of time behind the stop line and then continued to cross if the roadway is free. The next transition 'vstp' means the vehicle stopped before the stop line.

AG (vstp ∧ (y = 0))→(AG ≤1 vstp ∧ AF >1 vmvt).

The clock y that appears in the formula is used to specify the point in time when the vehicle stopped.

Declarative properties pdc: vehicle speed, vehicle position, crosswalk location

Procedural properties ppr: "Braking of the vehicle" is an event; "Vehicle deceleration" is an action.

Dissonance properties pds:

- Behavioral, "an alarm system alerts the driver to stop the vehicle".
- Attitude: "driving at a high speed can have very dangerous consequences".

IV. CASE STUDY

Example to cross a stop sign (STOP)

A vehicle moves on a rood at a speed of 50 km / h. A stop sign near a school appears at a distance of 500m away from the vehicle. Due to various sensors in the vehicle, we can collect the following data: Vehicle speed: 50 km/h, Position of the sign: 500m, Type of the sign is a stop; the driver is 35 years old. Hence the following observations: The driver drove his vehicle at a speed of 50km/h (Cognition 1) of type behavioral. The vehicle has to stop in front of a stop sign (Cognition 2). According to the driving law, the driver must start decelerating from a distance of 100 m before the stop sign. The fig.7 shows some variables used during the calculation.

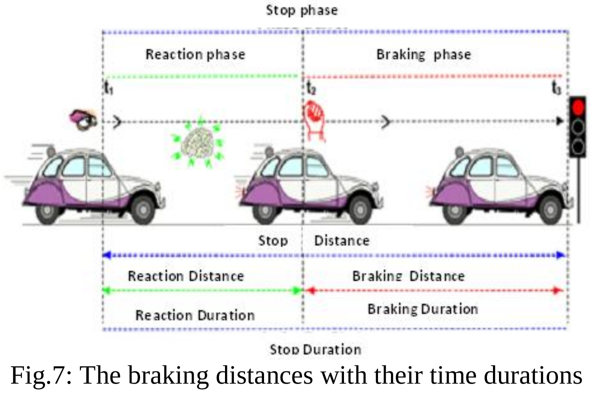

Fig.7: The braking distances with their time durations

Data of the example related to our knowledge base

The expected system will help in determining what the driver should do and what actions he should take to allow the vehicle to perform it.

The aim of our system is to anticipate what the driver should do. For instance, the driver should know the speed of vehicle (from the speed setting), the degree of adhesion of the road (depending on road conditions), and the degree of driver's fatigue. If he encounters a stop sign (from reading road signs) and the vehicle has not decelerated, so the system detects dissonance (before arriving at a stop sign. Thus, he must decelerate and act to comply with the stop sign before the pass line while giving priority to pedestrians. Each driver must know the driving laws and respect it.

The braking maneuver will combine four skills: speed control, steering, space margins and communication. When a driver sees a stop sign he must respect it ("stop the vehicle in front a stop sign") (declarative knowledge) and shall ensure to follow this series of actions that constitute the procedural knowledge:

1. Prepare to stop.
2. Report his intentions by slowing and activating his brake lights from a distance DD such as deceleration distance (DD) ≥ = braking stopping distance SD + 200m (or equivalent to a time duration t_d)
3. Begin to decelerate progressively the vehicle speed before reaching the stop sign from the stopping distance (SD) (or equivalent to a time duration ta)
4. Stop completely the movement of the vehicle (all tires of the vehicle must still immobile) for a duration tstp (e.g, = 20 ms).
5. Stop the vehicle in front of the stop sign before the passage of pedestrians, or stop at the line, if there is one; if he does not stop before proceeding to the intersection.
6. Also, the vehicle must still stop until all users (pedestrians, vehicles) have completely crossed the roadway (in both directions).
7. Look both ways, when the way is free then prepare for the start.
8. Start moving slowly to expand your view to continue the ride.

From these rules above, we can identify the actions' conditions that establish the conditional knowledge base:

1. Hand on the steering, looking forward, remove the right foot from accelerator pedal.
2. Place the right foot lightly on the brake pedal.
3. Stop the vehicle before the stop sign and don't block the crosswalk.
4. Maintain a fixed pressure on the brake pedal when attempting to stop.
5. The vehicle must still stop until all pedestrians leave the crosswalk.
6. Look both ways before proceeding to the vehicle movement when the way is free.
7. Drive slowly to expand your view.

Modeling of object knowledge related to our example

Context Cn = {O, E, P} with:

O: Objective 'driving vehicles', such as O = {O1 O2 ^ O3^ ... ^On} With O1objective of the process P1, O2 objective of the process P2, O3 objective of the process P3, etc.

E: Set of domain classes E = {Driver, Vehicle, Environment}

P: Set of processes that operates within the context Cn; P = {P1, P2, P3...Pm }, for example the process P1: A vehicle moves on a road where there is a stop sign; P2: Vehicle crossing a crosswalk; P3: Vehicle crosses a traffic light; and P4: Vehicle moves on a highway where there is a speed limit; etc.

In our example we are working on both processes P1 and P4.

Process P1: Vehicle moves on a road where there is a stop sign.

Formally, the process P1 is represented as P1 = {(OK1,1),(OK2,2),(OK3,0)}

1. (OK1, 1): The vehicle moves at a speed v at a distance d from a stop sign. The vehicle must stop.
2. (OK2 2): The vehicle stops moving (v = 0, d = 0) in front of a stop sign for a time duration t sec.
3. (OK3, 0): The vehicle crossed the stop sign.

(Ok1,1): The vehicle moves at a speed v at a distance d from a stop sign. The vehicle has to stop after a time t_d.

OK1 = {Cn, P1, R, type, psg, pdc, ppr, pds} with:

R = Driver x Vehicle x Environment

type = PreOK

psg = {activation time, lifetime, cond1, cond2}

cond1: The driver must start deceleration of the vehicle after detecting a STOP sign (from a distance DD or a duration t_a).

AG(vmvt ^ AppStop Sign → AF ≤td vdec)

cond2: The vehicle needs more time t_f to stop in front the stop sign since its appearance.

AG(AppStop Sign ^ (x = 0))→ AF ≤ tf vstp)

pdc={Right_feed_position, v, d, t}

ppr = {Braking (event), Stop_Vehicle (action)}
pds = {Changing_attitude (),Changing_behavior ()}
(OK2 2):The vehicle stops moving (v = 0, d = 0) in front a stop sign for a time duration t_w sec.
OK2 = {Cn, P1, R, type, psg, pdc, ppr, pds} with:
R = Driver x Vehicle x Environment
type = PreOK
psg = {activation time, lifetime, cond1}
cond1: The car will be completely stopped for at least one unit of time behind the stop line and then it can continue to cross if the road is free.
AG (vstp ^ (y = 0))→(AG≤ tw vstp ^ AF >tw vmvt)}
pdc = {position_right_feet, hands_position, v, d, t_w}
ppr = {accelerate (event), move (action)}
pds = {changing_attitude () changing_behavior ()}
(Ok3,0): The vehicle crossed the stop sign.
OK3 = {Cn, P1, R, type, psg, pdc, ppr, pds} with:
R = Vehicle x Environment
type = PostOK
psg = {activation time, lifetime, cond1, cond2, cond3}
cond1: Each user who uses the road finally releases it.
AG(vmvt→ AF free pstp) ^ AG(pmvt→ AF free vstp)
cond2: The vehicle must cross if no other user (pedestrian or vehicle) uses the road.
AG(¬vmvt ^ ¬pmvt → AF ¬vstp).
cond3: The driver must start the acceleration after the roadway liberation by users.
AG(free pstp ^ free vmvt → AF vmvt).
pdc = {v, d}
ppr = {} // empty set
pds = {} // empty set
Note the following proposals:
vmvt: vehicle in movement, case where the vehicle uses the pedestrian crossing,
vdec: vehicle in deceleration, case where the vehicle is decelerating,
vstp: vehicle stopped, case where the vehicle stopped before the stop line,
pmvt: pedestrian in movement, case where the pedestrian uses the pedestrian crossing,
pstp: Pedestrian stopped, case where the pedestrian is out of the pedestrian crossing,
AppStop Sign: The appearance of the stop sign.

Diagnosis
By observing the activities of the driver in the car (the detection of the location of the hands, the identification of movements of the head, feet positions, directions of gazes, etc...) and considering what happens outside the car (signs, vehicles and other users localizations, directions of the bends, etc.), our system can anticipate possible actions that the driver must perform. Combining driver's anticipation (Internal control of driver) and the external control of the road environment (such as radars or cameras), our system could alert the driver when the intended action could be dangerous. The system will provide a message "Attention a stop sign" if the driver had the intention to accelerate or keep the same speed.

Detection of dissonance
Acquire the observations:
Cognition 1 (Behavior): The driver keeps the speed of his vehicle at a speed of 50 km/h at a distance of 100 m before the stop sign.
Identify the suitable attitudes:
Cognition 2 (Attitude 1): The vehicle must stop at a stop sign.
Cognition 3 (Attitude 2): The non-stoppage of the car leads to a fine of €100.
Cognition 4 (Attitude 3): The non-stoppage of the car leads to dangerous consequences.
Compare observations to attitudes:
- cognition1 x cognition 2
- cognition1 x (cognition2 ^ cognition 3)
- cognition1 x (cognition2^ cognition 4)
If one of the comparisons is false this implies the existence of a dissonance.

Dissonance reduction
To eliminate the contradictions of the above example it is:
- To change the driver behavior (cognition 1) in order to be consonant with the attitude cognition (cognition 2)
- To change the attitude by adding new cognitions (cognition 3 and cognition 4).

The following flowchart shows the diagnosis process to detect and resolve dissonance (Fig.8).

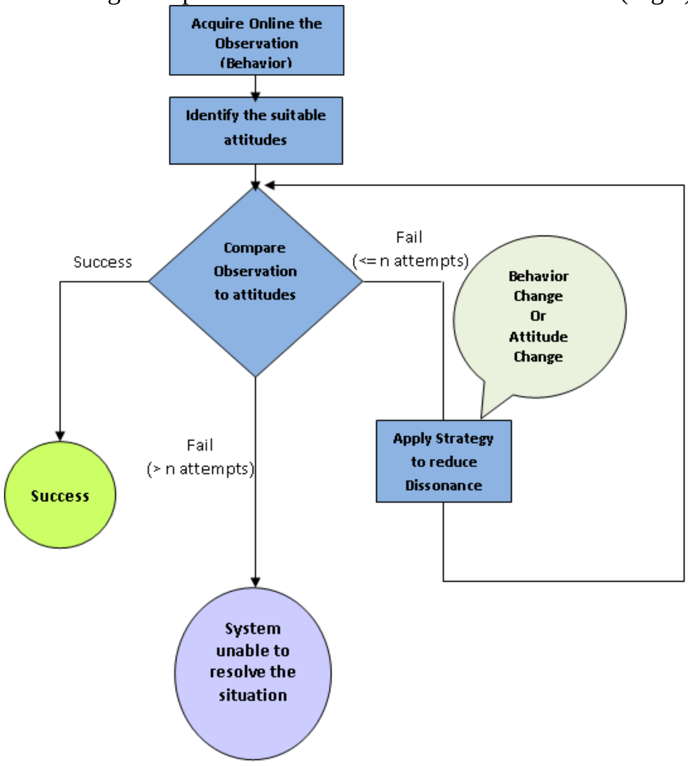

Fig.8 : Dissonance process diagnosis flowchart

Changing behavior

The model is made to prevent contradictory phenomenon which might occur, to shy away from risk situations or to protect them. This can occur while eliminating or minimizing the importance of the dissonant cognitions. It means to prefer or to ignore any embarrassing information. The model must add motivators to change the behavior of the driver. Thus, the system must test again the dissonance.

These motivators are either active or passive. Example of passive motivators, the model alerts the driver by an indicator (visual and/or audible). For active motivators, it is to have an authority on mechanical components of the vehicle (accelerator, brake or flashing ignition).

Changing attitudes

In the case where the driver has not concretely changed his behavior, the model acts on the dissonance itself. This resolution method is to rationalize the driver behavior by adding new cognitions (Cognition 3 and 4) allowing the driver to change his attitude.

V. CONCLUSION

The cognitive dissonance approach is crucial in the context of our research because it is an excellent preacher of driver's behavior by his influencing on the diagnosis of risk. Indeed, the discomfort issued from the cognitive dissonance may generate a risk; as long as it is not reduced it implies adverse behavioral intentions.

The qualitative representations of drivers' cognitive tasks and the existence of cognitive dissonance in these representations predict an unpleasant situation. Our study aims to predict drivers who engage in disturbing behavior or in potentially dangerous situations (the hands are not on the steering, the foot is not at the correct position). Thus, we studied our research objectives on several levels:

- By exploring different representations of the system (vehicle-driver-road environment).
- By identifying their components as elements affecting the value of cognitions (attitudes, values, decisions).
- By highlighting the cognitive dissonance in these representations.
- By expressing the facts and tasks that the driver must turn away in the right situation.

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