AFFORDANCES AND COGNITIVE CONTROL OF DYNAMIC SITUATIONS: THE CASE OF DRIVING

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Abstract

Driver's models are usually based on two basic dimensions (information's hierarchical level and temporal span of the activity) used to describe the cognitive control of a dynamic situation. Hoc et al. (2004) general model proposes four types of control differentiated by the information's level of abstraction and by the origin of information. All those types of control need perception. The concept of affordance may account for a part of the perception. Thus, after a presentation of this concept and its implications, contributions and limits to the cognitive control of affordances will be explained. Moreover, methods are proposed to study affordances and non-affordances perception in driving.

Keywords: *affordances*, Cognitive control, Driving, Dynamic decision making

Errors during an activity can be due to a lack of information. Even if models of activity's cognitive control consider that picking up information in the environment is crucial to control the activity, they do not explain how perception is functioning. Now such an explanation is necessary in order to display information that are missing during the activity and thus to avoid errors. The purpose of this communication is to present an ecological approach to perception that can be useful to understand how information are picked up in the environment during the control of an activity as driving.

1 Driver's models

Since the theoretical frame to analyze driver's behavior by Gibson & Crooks (1938), driver's models have generally considered that driving activity is an activity of control of risk's situation (e.g. Fuller 1984). The driver's behavior depends on the level of risk he is accepting and his individual goals. These driving risk's models account for the control of patterns of actions by the driver. However, driver's models have to explain different driving tasks as (a) itinerary's following or (b) manual control of direction. Thus, these models are incomplete.

To describe and explain in an integrative way all the activities composing driving, hierarchical models are adequate (Michon 1985). Actually, driving tasks can be organized into a hierarchical model in three levels according to their level of activity's cognitive control (Van der Molen & Bötticher 1988). The lower level is “operational” (e.g. vehicle's control) and concerns actions about very short-term (some milliseconds). It is skills-based and uses information that is signals. The intermediate level is “tactical” (e.g. vehicle's guidance) and concerns actions about short-term (some seconds). It is rules-based and uses information that is signs. The higher level is "strategical" (e.g. itinerary's following) and concerns actions about long-term. It is knowledge-based and uses information that is symbols and concepts (Rasmussen 1986). The different levels influence each other. In sum, hierarchical driver's models have to take into account two dimensions: (a) hierarchical abstraction of information and (b) different temporal span. Thus, it seems that hierarchical models of driving activity might be considered as specific cases of cognitive control of dynamic situations.

2 Cognitive control of dynamic situations

Actually, controlling dynamic situations consists in keeping this situation within acceptable limits. In driving, those limits can be those that permit traveling in safety (Gibson & Crooks 1938) avoiding risk situations. Hollnagel's COCOM model (COntextual COntrol Model 1993) proposes four temporal spans of control (strategic, tactical, opportunistic, and scrambled). Hoc *et al.* (2004) consider that the shortest temporal spans (opportunistic and scrambled) correspond to reactive controls because they are directed by the data from the environment (external control). The longest temporal spans (strategic and tactical) correspond to anticipative controls founded on internal representations, goals (internal control). The same authors simplify Rasmussen's abstraction hierarchy too, considering that signs and symbols need an interpretation but not signals. Thus they consider two levels in abstraction hierarchy: a symbolic/cognitive one and a subsymbolic/non cognitive one. The cognitive control of dynamic situations model from Hoc *et al.* (2004) simplifies and crosses the dimensions founded in hierarchical models of drivers: control's abstraction level (symbolic or subsymbolic) and temporal span (external control for short-span or internal control for long-span). This model (figure 1) affords accounting of the operator's decision-taking to emit a specific behavior or another one. As in hierarchical driver's model, symbolic and subsymbolic activities can interact: symbolic activities supervise the subsymbolic ones, and the last ones come out in consciousness at the symbolic level.

Driving tasks can be classified in this model. Manual control of the vehicle's direction or urgency braking to avoid collision can be grouped together as reactive activities based on subsymbolic data. Taking the decision of overtaking or slowing down seeing an intersection are anticipative activities based on subsymbolic data. Taking the decision of stopping at the next gas station after seeing the petrol warning light on or taking the decision of slowing down approaching a red light are reactive activities based on symbolic data. Consulting a map to choose an itinerary or looking for direction information on road signs are anticipative activities (supervision) based on symbolic data.

3 Perception-action in driving

Even if anticipative activities are above all guided by internal data, guidance based on external data can nevertheless take effect. Thus, perception processes are the foundations of the four types of control. The theoretical frame by Gibson and Crooks (1938) provides an interesting idea on the role of perception in driving. Those authors consider that driving is locomotion-like functioning but mediated by a tool, the car. In their conception, driving is considered as series of reactions guided by the perception of the paths the car can take to avoid collisions and other problems. The whole of those paths allowing staying in safety is called the Field of Safe Travel (FST). The FST perception is based on the perception of the valences of the different visual environment areas. Areas with a negative valence (dangerous areas) are the limits of the FST. They are perceived and cause reactions (braking, accelerating, turning the steering wheel) which permit to the car to stay in the FST. Limits of FST can be physical, physiological, standing and moving objects, potentially or legally barriers. In sum, perceiving the FST consists in perceiving what we can or we must do to drive in safety.

This theoretical frame has been developed by Gibson (1979) to create an ecological approach of perception-action coupling. In his theory, opportunities of actions (*affordances*) are directly perceived without inferential processes. Thus, the FST is the whole of *affordances* that allow, if they are actualized, to avoid dangerous situations. Making the assumption that one can perceive its own *affordances* by direct perception means that one picks up information in the environment about the properties of the individual-environment system (Stoffregen 2003). An *affordance* is thus neither a characteristic of the environment nor a property of the individual: it is a property of the individual-environment system which is emerging from the dynamic of the system and which can be perceived directly by the individual. Perceiving an *affordance* is perceiving an actual property of the system in the present that can influence the dynamic of the system in the future (perceiving an *affordance* consists in perceiving what may happen). Different *affordances* can exist simultaneously in the system. The one which will be actualized is the one which is complementary to the intention of the individual if there is co-occurrence between this *affordance* and this intention (Stoffregen 2003).

Even if traditional approaches of perception deny the possibility of direct perception, some authors recognize that individuals are able to acquiring information about their relationship to the environment, thus their *affordances* (e.g. Norman 1988). Yet it has been experimentally shown that *affordances* can be perceived directly by picking up in the optic array of body-scaled information (e.g. Mark 1987). However, if the environment contains symbols (as road signs in driving), it can be difficult to assume that *affordances* are directly perceived because symbols are arbitrary geometrical configuration that requires, to be understood, to know its significance: a concept linking the symbol to its signification for the individual is needed (Winter 1998). Thus in an environment with some properties needing interpretation, emergent properties of the individual-environment system may probably need mediating processes to be perceived as *affordances*. Besides, in the context of distributed cognition (Zhang & Patel, in press), *affordances* are considered as distributed representations extended across the individual and the environment. The properties and the information of the environment specify an external representation space and the properties and the knowledge of the individual specify an internal representation space. In this theory, *affordance* space emerges either (a) from the conjunction of allowable actions of the two spaces, or (b) from the disjunction of constraints of the two spaces. Even if this conception is far from the direct perception approach, *affordance* is even so considered as a property of the environment-individual system.

In sum, two types of perception of *affordances* (direct and mediating) are existing simultaneously. This is in full agreement with the idea of the coexistence of the direct and the mediated theories of perception (Norman 2002). Thus the perception of FST is direct for “natural” *affordances* and mediated for those based on symbols.

4 Affordances and cognitive control of dynamic situations

As it was said above, the four types of cognitive control need external information at different degrees. In the field of driving, perception of the FST furnishes information needed by reactive activities and also by a part of anticipative activities.

In the case of anticipative activities based on subsymbolic data, internal data as intentions guide the behavior and what is perceived by the individual is subsymbolic. Thus, it can be considered that the chosen action is the one that is afforded by the environment-individual system and that corresponds to the intention of the driver. This is similar to the Stoffregen's idea about the actualization of an *affordance*. Thus perception in this cognitive control type is perception of *affordances*, and this perception is direct because data don't need interpretation so they are not symbolic (see Warren 1995 for a review about *affordances* studies in natural environments).

The reactive activities based on subsymbolic data are continuous fine tuning of ongoing acts which permit to stay within margins of safety. In the case of driving, they are the reactions which permit to the vehicle to stay in the FST. Studies have shown that these reactions are based on information contained in the optical flow (e.g. time-to-contact; see Schiffand & Arnone 1995 for review).This on-line control of movements is generally discussed in the research on dynamic coordination. In dynamical systems, continuous variations in the parameters of the environment lead to discontinuous changes in the behavior. Now judgments of *affordances* and their actualizations changes also on a discontinuous mode, whereas variations of environment's parameters are continuous. According to Stoffregen (2000), this similitude can't be coincidental and thus it seems possible that perception in reactive activities based on subsymbolic data can be based on *affordances*-like perception.

For the reactive activities based on symbolic data, if the information is orders, its perception can't have the form of *affordance* perception because it does not inform on what is possible to do but only on what must be done. It furnishes a goal not an *affordance*. In the others cases (information in relation with actions not with goals), perception can not be direct perception of *affordances* because of the nature of the data which need interpretation to be understood. Thus, perception is necessarily mediated. It seems that the reactive character of the activity and the prospective character of *affordances* are incompatible. However, actualization of an *affordance* depends on the complementary and the co-occurrence of this *affordance* and an intention. Now, a reactive activity to symbolic data is possible only if the properties of the environment-individual system afford it (e.g. in driving, when the light becomes red, it is possible to brake to stop at the light's level, only (a) if the distance needed to stop the vehicle, depending of the dynamic of the environment-vehicle system, is shorter than the distance between the vehicle and the red light, and (b) if the individual's intention is to react to the symbol). Thus, it is necessary to perceive *affordances* to react to a symbolic data. In order to consider that perception in this type of cognitive control is a mediated perception of *affordances*, a model of the cognitive control of dynamic situations must take account of the necessity of internal references even in situations of control in which external references are most dominants.

In the case of anticipative activities based on symbolic data, perception is useful to have information to execute the plan of activity, or to modify this plan, or to establish activity's goals. Now perceiving *affordances* of the environment-individual system is not helpful to actualize plans. It only deals with information related to actions.

In sum, when data needed to control a dynamic situation are "natural", subsymbolic, it seems that their perception could be considered as *affordances* direct perception. When data are symbolic, if they are related to orders or goals, perception of this information could not be *affordances* perception; if they are related to action (as it is possible in reactive activities) their perception could be *affordances* mediated perception.

5 Problematic and methodological propositions

One of the reasons of problems in dynamic situation's control is the lack of perceived information. Some of those missing information can be displayed to individuals. However, the display mode can not be the same according to the type of the needed information. In the case of control based on *affordances* perception, information emerges from the dynamic of environment-individual system; thus, what is missing has to modify this system in a way permitting the emergence of the information. In the case of control based on another perception type, the information isn't a property of the environment-individual system but information independent of this system that permits to actualize the representation of individual's situation. Thus, activity as to be analyzed considering the type of information (*affordance* or independent) on which it is based.

In the theoretical context described above, it can be assumed that drivers perceive, at least partly, their environment in an *affordances*-like perception way (FST perception). An activity analysis of this activity, based on the information type, can be carrying out establishing in what is perceived, what belongs or not to the FST. In order to carrying out this distinction, methods from ecological psychology and ergonomic psychology are useful. Actually, *affordances* judgment method should provide information about the perception of the FST. However, instead of trying to establish perceived limits of a specific action, presenting to the driver a picture of natural driving situation asking him "if you were driving, what could you do?" seems permitting accessing to a global FST perception. To know some environment data on which is based this perception, the "What? (What element of the picture provides you this information?) Where? (Where do you see in the picture you can do that?)" method could be useful. In those chosen situations, symbolic independent information can be added in order to test if this information influences the FST's perception, or only representation of the situation, like it is assumed.

In order to know if what is perceived by drivers (*affordances* and independent information) is really guiding the driving activity, a comparison between *affordances* judgments in a moving view of the environment without acting in it and the actions carrying out in this environment that can be observed can be made. To be sure that, in the "acting situation", actualized *affordances* are related to the listed ones, a complementary intention to the listed *affordances* has to be given to the driver.

6 Conclusion

In this communication, it has been shown that the *affordances* theory and cognitive control model can be complementary to understand how perception is functioning during an activity. Methodological propositions have been made in order to test the pertinence of those models combination. Analyzing driving activity taking the nature of the perceived information into account is necessary to know how displaying missing information without increasing driver's attentional load. Ecological interfaces adapted from those used in processes supervision (Vicente & Rasmussen 1990) could be the best to display information that must be perceived in an *affordance*-like way and traditional interfaces should be chosen to display independent information.

Fuller R (1984) A conceptualization of driver behaviour as threat avoidance. Ergonomics 27: 1139-1155.

Gibson JJ (1979). The ecological approach to visual perception. Houghton Mifflin, Boston.

Gibson JJ, Crooks LE (1938) A theoretical field-analysis of automobile-driving. American Journal of Psychology 51: 453-471.

Hoc J-M, Amalberti R, Cellier J-M, Grosjean V (2004) Adaptation et gestion des risques en situation dynamique. In Hoc J-M, Darses F (eds.). Psychologie ergonomique: tendances actuelles. PUF, Paris, pp. 15-48.

Hollnagel E (1993) Human Reliability Analysis: Context and Control. Academic Press, 1993

Mark LS (1987) Eyeheight-scaled information about *affordances*: a study of sitting and stair climbing. Journal of Experimental Psychology : Human Perception and Performance 13: 361-370.

Michon JA (1985) A critical view of driver behavior models : what do we know, what should we do ? In Evans L, Schwing RC (eds.). Human Behavior and traffic safety. Plenum Press, New-York, pp. 485-521.

Norman D (1988) The Psychology of Everyday Things. Basic Books, New York.

Norman J (2002) Two visual systems and two theories of perception: An attempt to reconcile the constructivist and ecological approaches. Behavioral and Brain Sciences 25: 73-144.

Rasmussen J (1986) Information processing and human machine interaction. An approach to cognitive engineering. Elsevier, New York.

Schiffand W , Arnone W (1995) Perceiving and driving: where parallel roads meet. In Caird J, Flash J, Hancock P, Vicente K (eds.). Local applications of the ecological approach to human-machine systems. LEA, Hillsdale, NJ.

Stoffregen TA (2000) *Affordances* and events. Ecological Psychology 12: 1-28.

Stoffregen TA (2003) *Affordances* as properties of the animal-environment system. Ecological Psychology 15: 115-134.

van der Molen HH, Bötticher AMT (1988) A hierarchical risk model for traffic participants. Ergonomics 31: 537-555.

Vicente KJ., Rasmussen J (1990) The ecology of human-machine systems II: Mediating " direct perception " in complex work domains. Ecological Psychology 2: 207-249.

Warren WH (1995) Constructing an econiche. In Caird J, Flash J, Hancock P, Vicente K (eds.). Global perspectives on the ecology of human-machine systems. LEA, Hillsdale, NJ.

Winter S (1998) Expectations and linguistic meaning. Ph.D. thesis. Cognitive Science Department, Lund University. http://www.lucs.lu.se/People/Simon.Winter/Thesis/.

Zhang J, Patel VL (2006) Distributed cognition, representation, and *affordance*. Cognition and Pragmatics (in press).

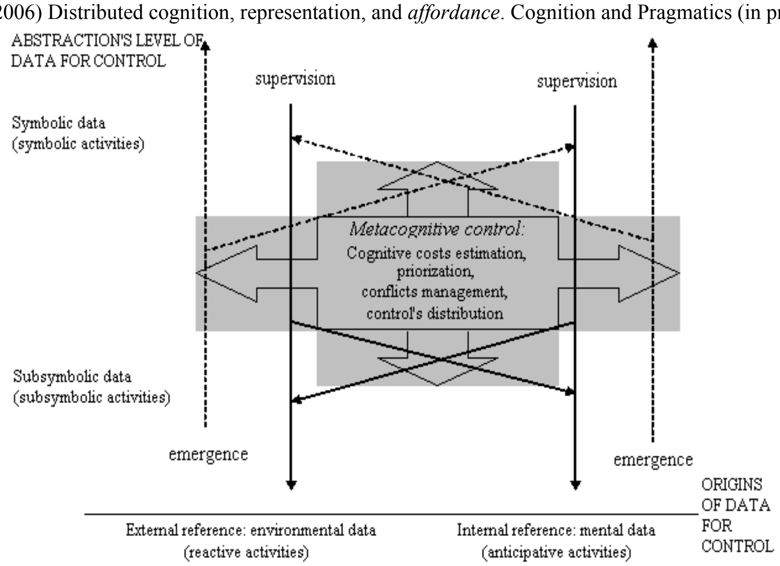

Figure 1: Model of cognitive control (according to Hoc *et al.*, 2004). Types of cognitive control are presented according to two dimensions: control's level of abstraction and origins of data for control.