An Architecture for Agent's Risk Perception

Nuno Trindade Magessi[a], Luis Antunes[b]
[a] nmaggessi@hotmail.com
[b] xarax@di.fc.ul.pt
GUESS/ LabMag/ Universidade de Lisboa, Portugal

KEYWORD

Risk Perception
Architecture
Cognitive Modelling

ABSTRACT

One of the critical issues in agent's risk decisions is perception, specially because it assumes a key role on the decision process. This subject has not received enough attention in agent's modelling literature. Until now, the main focus has been on the decision making process of agent's and consecutive interpretation of their behaviours. In this sense, risk literature needs to focus on perception. It is through this cognitive process that all relation between individuals and the risk event will be recognized. In this sense, agent's make decisions about a specific type of risk by taking into account their own perception. To help understanding how perception works, it became necessary to design the mechanisms and consequent context dimensions involved on it. Following this objective, we defined an architecture explaining this cognitive process. An architecture for agents' risk perception complemented by the associated factors of context dimensions, in order to understand this subjective process, that happen in our minds .

1 Introduction

Risk and its perception continue to interest researchers. One of the issues is modelling perception of agents under uncertain decisions. From psychology and neuroscience literature [Freeman W.,1991], we know that this mind process is highly complex, involving many subsystems of the brain. Physiological mechanisms involved in perception works through neuronal assemblies like awareness [Freeman W.,1991].

Until recently, most of the work done towards simulating intelligent virtual agents (IVAs) in multi-agent based simulation (MABS) systems has lacked realistic techniques for risk perception and has focused on agent planning and behaviour control. Even though recent studies have produced theoretical models for individual senses and also linked framework that integrates all these demarches [Steel,T. ,et al,2010]. IVAs is a new emerging and multidisciplinary field of knowledge. It is making fast progresses, owing its inherent attractiveness to diverse fields, strongly related to VEs of Multi-Agent Systems (MAS). Virtual humans [Balcisoy,S.,2001] must have autonomous behaviours, look realistic and be able to interact with each other on virtual scenes, representing the real world. One of the most important characteristics of IVAs is the ability to perceive the current situation of an environment where they are inserted. Many works had the goal of providing agents with a higher degree of realism [Herrero,P.,et al.,2002]. And realism has often been sought, providing human-like appearance or behaviour. However, the realism of risk perception has been continuously ignored on situations involving uncertainty.

Can we represent risk perception as a computational process? What type and respective characteristics a consequent architecture should have? This article aims to introduce and discuss an architecture resembling the cognitive process that people typically use when they perceive a risky event and have to make a judgement about it.

The article is organised as follows. Next section describes recent efforts done in modelling virtual perception. On section3, we describe recent discoveries about risk perception. Section 4 introduces our architecture representing risk-perceiving agents and consequently risk-aware. On section 5, we present the context dimensions of factors that affect risk perception, fitting the proposed architecture. We discuss the new architecture with reality and other architectures, on section 6. Finally, section 7 summarises the article and offers some guidelines for future research.

2 Past efforts in modelling virtual perception

Agent's perception modelled by multi intelligent virtual agents (MIVA) has being considered a descriptor of sensors, providing agent's with the knowledge about the context surrounding them. MIVA modellers base their definition of perception on Chenney's work [Chenney,S.,1996],[Card,S.,et al,1983].

Chenney defined perception of autonomous agents as a process of interaction with the environment to collect and exchange information about the environment and the agent itself [Chenney,S.,1996],[Card,S.,et al, 1983].

He divided perception into categories of active sensing, passive sensing and feedback sensing. Active sensing happens when information is continuously being provided, regardless of the agent being explicitly looking for it. On the other hand, in passive sensing, the "data is only generated when required" like in a query procedure. Finally, feedback sensing is "considered a special case of passive sensing when it is not integrated with the general sensing system". "It is coupled to the motor controllers that require the feedback" [Chenney,S.,1996; Card,S.,et al,1983]. So in sensory systems, perception is an active process of seeking information from the environment [Tu, X.,et al.,1994],[Terzopoulos,D.,et al,1994].

Pew [Pew, R., et al,1998] recommends as a top short-term goal to improve situation awareness modelling. In his words, he suggested to "include explicitly in human behaviour representation a perceptual front end, serving as the interface between the outside world and the internal processing of the human behaviour representation" [Pew, R., et al,1998]. Situation awareness plays a central role in cognition, which comprises the entire spectrum of cognitive activities from perception (such as lower-level vision activities), to high-level cognition (such as understanding, reasoning, and decision-making). In most computer generated forces, the modeller can focus the application development effort on object representations and cognitive processes specification. An example of this is the cognitive agent, the COGNET. It is based on Rasmussen's integrated theory of human information processing [Rasmussen, J., et al., 1982]. In COGNET [Das, S., et al, 2000], the role of the perception mechanism is to transfer the data obtained from the external world to the cognitive processor.

IVAs have been developed with very varied aims and features, and, for this reason, perception in those agents has been modelled in diverse ways, depending on target for what they were designed. Perception in IVAs can be focused on implementing the processing of sensory inputs for the cognitive process.

So from the described models of perception, COGNET is the one with more similarities to what it is risk perception. COGNET basically converted the input data into the symbolic format used by the cognitive model, with some incursions on modelling the human perception mechanisms.

3 Risk perception updates

Risk perception is defined as one of the mind processes composed by collecting, selecting and interpreting signals about uncertain impacts of risk events and culminating in a subjective judgement [Wachinger, G., et al,2010]. These signals can refer to direct observation or information from others. Judgement is in fact the recognition and identification of risk event

by individuals. Risk perception doesn't involve risk valuations. Subjective or objective probabilities and consequent magnitude of impacts is related to risk assessment and not with perception.
Perceptions may differ depending on the type of risk, the risk context, the personality of the individual, and the social context [Wachinger, G., et al, 2010].
Individuals perceive their risks, through thinking and judgment about the seriousness of risks they will face. Yet risks cannot be perceived in the sense of being taken up by our senses, as are images of real phenomena. The mental models or other psychological mechanisms that people use to judge risks, such as cognitive heuristics are internalised through social and cultural learning and constantly influenced by society.
As it was portrayed above, psychological, social and cultural dimensions influences risk perception. However, the aforementioned dimensions are all interconnected, strengthening up or attenuating each other [Wachinger, G., et al, 2010]. Considering these interactions, a structured framework was improved to provide an integrative and systematic perspective of risk perception. It includes four interconnected dimensions: heuristics, cognition, social and cultural. This framework was initially displayed by [Renn,O.,2008] and adapted from the generic model of [Breakwell, G.,2007].
All four dimensions are relevant in order to gain a better and more accurate understanding of risk perception. In spite of many questions and ambiguities in risk perception research, one conclusion is beyond any doubt: abstracting the risk concept to a rigid formula and reducing it in two components, such as "probability and consequences", does not match people's intuitive thinking of what is important when making judgments about the acceptability of risks. [Slovic,P.,1992] Notwithstanding the described framework clearly misses critical aspects of risk perception like episodic memory or working memory. Risk perception, like other perception types, is generated by physical mechanisms inside the brain, like amygdale or striatum. In place, different sub-systems of brain help individuals improving their judgements about risk assessment and consequently making better decisions about it. Recent developments suggest that perception has some features and working patterns similar to awareness. Perception manifests according neuronal assemblies theory [Freeman W.,1991]. Neuronal Assemblies are defined as neuronal coalitions in large scale and highly transient, establishing connections between the neurobiological molecules and cellular components. The process occurs when several neurons from various neuronal columns within different sub-systems of brain unify and act harmoniously together. Therefore, the more complex are the stimuli, the greater are the complexity of neuronal sets and number of recruited neurons. Several experiments reveal that neurons are able to join quickly, forming functional groups to accomplish a certain task. Once this task is completed, the group dissolves and neurons are again able to fit on other sets, to fulfil a new task. More specifically, most of the literature agrees that our sensory perceptions as well as our abstract thoughts correspond to the activity of neuronal assemblies [Freeman W.,1991]. An activity that is subject to a complex set of distinct dynamics.

4 A proposed architecture

After efforts of defining architectures to perception, our main goal is design an architecture that embraces the new features of cognitive science, in order to describe specifically risk perception. Independently of trying to meet an embracing architecture that fulfils all risk types and contexts, it is fundamental to maintain integrated the subjacent dimensions with impact on risk perception. This means, there are factors who help us to build a particular trial about a specific risk. The perceived risk comes from the interaction of these factors. This is different from defining a model. Under the same architecture we can have many models, depending of the risk type and context.
We claim that a risk perception architecture must contemplate the process behind the way we perceive risks, subject to the dimensions that influence it. First of all, agents receive stimulus

or signals about an occurrence of an event

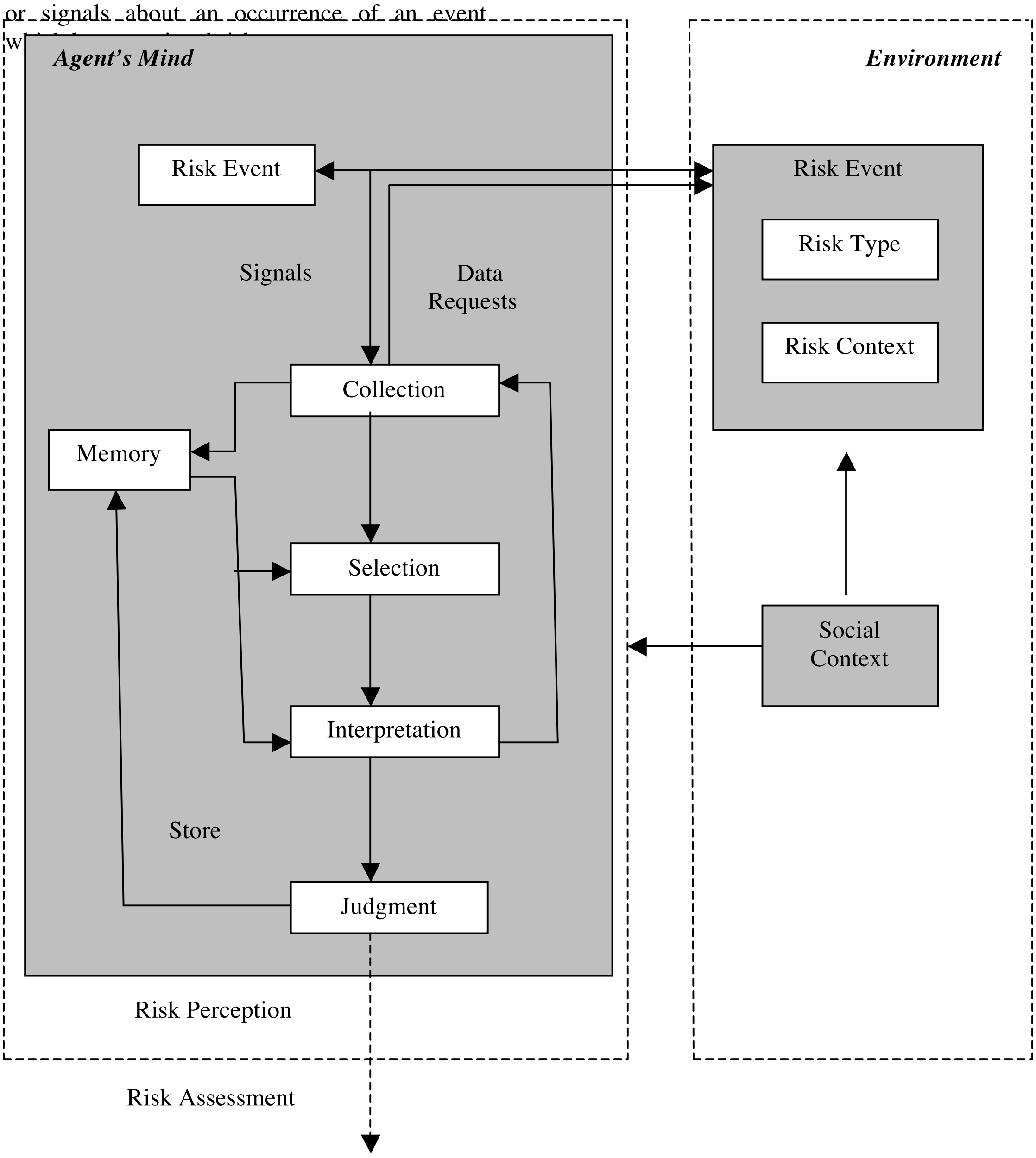

Fig. 1 – Risk Perception Architecture

Risk is a concept build on human minds and recognisable by individuals, distinct from danger. Risk could be generated inside agent mind or externally on environment surrounding him. After these inputs had arrived into mind through electrical signals in our nervous system, intermediate by sensors, the cognitive process of risk perception starts [Goldstein,B.2009]. Those electrical signals are created in the receptors, which transform energy from the environment.

4.1 Step1: Collect

The first step is to collect signals in order to recognize risk. They are collected from agents memory or more frequently from environment.

Agents are going to search on their short term memory, through the working memory interface, any equivalent sign which will allow him to establish an immediate judgement. Working memory is the subsystem of brain that actively holds multiple pieces of transitory information in the mind, where it can be manipulated. This involves execution of reasoning and comprehension making them available for further information processing [Becker, J, et al,1999]. In this sense, if any similar sign was not found, the search process continues searching on episodic memory. The objective is to achieve reference points established to support analogies between risk events occurred in the past and the current one. Thus, identifying quickly the risk, less are the mind resources consumed. If agents cannot make any kind of analogy with past risks integrated on their memory, then they move forward with the collection of external signs, available on surrounding environment. **(see fig.1)**

Collection stage outlines relevance, since it is commonly on this first stage that individuals, consciously or unconsciously react without making any type of reasoning. A good example is to receive an external sign that wakes the fear about a specific risk. Fear activates amygdale which generates a fast and negative judgement about risk event. Consequently, individuals do not activate their algorithmic mind. They react automatically, in sense of avoiding risk.

However, if agent receives a signal not emotionally related, they start reasoning in order to obtain a rational judgement and then going further by selecting inputs.

4.2 Step 2: Selection

The second step is the selection of signals that were collected. Selection embraces the functionality of filtering data in order to facilitate next step, interpretation. This happens because agents minds have a limited capacity of processing data. Typically, human brains collect lots of data in order to understand a specific risk, in consequence of beep alerts. Agents like individuals want to achieve a fast judgement, in order to avoid the suffering of negative impacts. Selection supports mind tasks like sorting and filtering signs, in order to synthesise them [Wachinger, G., et al, 2010]. The major intuit is to prepare collected data to be easily interpreted. The success of selection is verified after interpretation. So, it is on interpretation step, that agents see if they need more inputs or inputs with more quality to recognize risk.

4.3 Step 3: Interpretation

After selection, agent risk perception goes through a third step: interpretation [Wachinger,G., et al,2010]. On this step, an agent understands the input data selected earlier. It is the step where cognition dimensions have a substantial impact on the way that risk is understood. It is the step where signs are merged and related each other. On this step, agents establish mental bridges between input data and the consequences about what is going to happen on the risk event. It is the step in which mind assign semantic to input data. It is a complex step, involving many subsystems of the virtual brain, restricted to its limited capacity. Probably this is like reality and one of the steps where neuronal assemblies consume a lot of brain resources. Next step arises when agents consider the interpretation done and acceptable, which means that it is when signs were assimilated. Learning is confirmed when agents reproduce the meaning of the signs in their minds. Even if it is at an elementary form. The acceptance appears if a kind of satisfactory logic was achieved. This is a stationary point of trust, offering to agent the comfort of facing risk event. It is on interpretation, that agents establish reason about signs and compare with similar experiences that happened in the past. If agent cannot interpret correctly or he isn't sufficiently confident, he turns back and demand more external data.

4.4 Step 4: Judgement

The trial step is the last one from perception and its main target. It is the second stationary point or moment of trust. Notice that a judgement is not an assessment or a decision at all. Decision is other cognitive process, in which an agent makes a decision of accepting or not risk . And of course, it is out of the boundaries of perception. The trial has the incumbency to weight and balance which signs fits better the reality of future event. It is important to remember that this judgement is individual and could not match with reality. It is a subjective reality generated individually at agents mind. The expected output is the achievement of a recognition that will help agents to assess and decide if they take or mitigate the risk and how they will do it. As a subjective perspective of risk, assessment is the instrument to check the evolution of risk. Agents follow up on risk based on the expectation they generated about the event. They make comparisons between the scenario built on and the evolutionary landscape of risk, until the event occurs. If by chance a gap emerges on perception, then agents could return back. If they noticed, they turn back to reasoning at interpretation step or secondly collecting new external data. An interesting point is the fact that judgement is archived in agent´s working and short term memories, unlike the perception at all , which is stored on episodic memory **(see fig.2).** The occurred perception will be used to perceive future events of risk. Perception is a complex, dynamic and ultra fast cognitive process. In terms of risk, perception happens continuously since agents have to monitoring the constant evolution of risk until the event occurrence. In this sense, perception has a repeated frequency.

4.5 On behalf of hybrid architecture

The proposed architecture is in consonance with [Georgeff, M., et al.,1989].
An agent is represented by a system capable to perceive through sensors and act according inside a specific environment [Russel, S. et al.,1996]. The agent is enriched by a set of properties typically belonging to him. For example autonomy to judge, temporality to remain or not interacted with environment, communication through the exchange of data with environment or other agent's and proactive in exhibiting a behaviour oriented to an objective, the judgement. Beside these properties, architecture offers to agent's capacity to react to stimulus from environment, but also to adapt into changes from the same environment and rationality.
Unlike other taxonomies [Alvares, L., et al., 1997] the architecture brings the agent to be reactive and cognitive. This means that in a certain measure, agent is modelled through states of mind, although with evident similarities and differences from a Belief, Desire and Intention architecture (BDI) or through explicit representation of perception [Bratman, M. et al, 1987]. Similarities because architecture adopts a psychological inspiration to define the structure of the agent by having components like beliefs, capacities, choices and compromises [Mora, M. et al. 1998].On other hand differences, because architecture is composed by modules representing functionalities important to agent pursuit his targets.

5 Dimensions affecting perception

As was described above, there are four main dimensions of factors that affect the perception of any risk. We could consider the physical aspects of brain functioning as a fifth dimension, but we prefer to avoid it at this stage because many important biochemical aspects are not understand yet. At the same time, it would increase the complexity of the architecture. We prefer to delay, until those aspects are better known and consequently more accurately represented.
These context dimensions of factors influence the functioning of the agent's architecture in what concerns. Cultural dimension is composed by factors intervening directly in perception process or indirectly through the impact on social factors or cognitive factors that will interfere in perception. The first two dimension, heuristics and cognition are endogenous to agent mind. On the other hand, social and cultural are exogenous and consequently not controlled by agent mind **(see fig.3)**

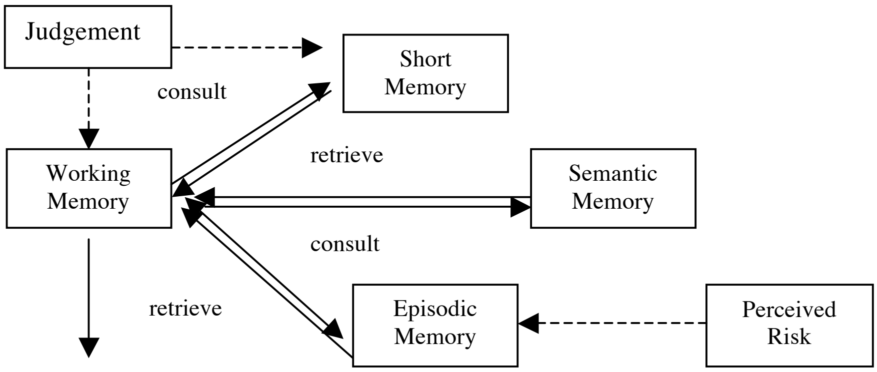

Fig. 2 – Memory System for Risk Perception. Working Memory is the interface to access into other types of memories

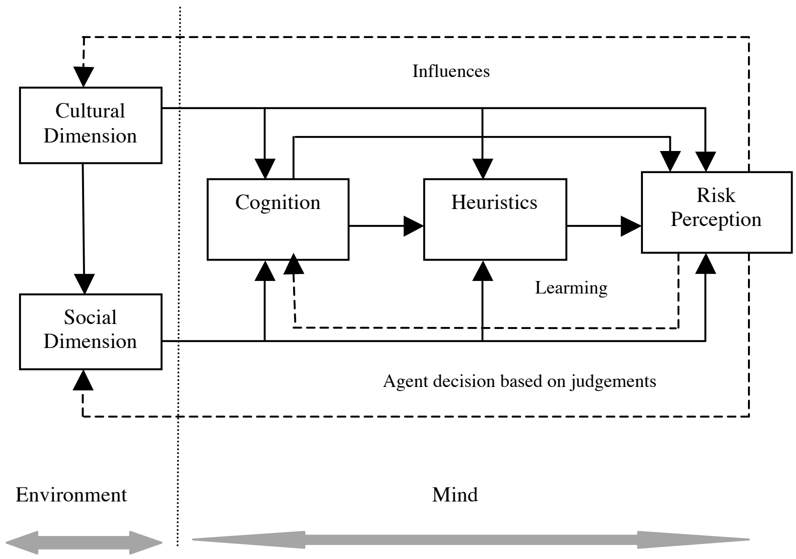

Fig.3 – Dimensions and risk perception dynamic interaction. Heuristics(CH-Collective Heuristics; ICS-Individual Common Sense); Cognition (K-Knowledge; S-Stigmas; B-Beliefs; RA-Risk Aversion; E-Emotions); Social Dimension(OC-Organisational Constraints; EPS- Economic and Political Structures; SV- Social Values and Trust; PV-Personal Values and Interests; SS- Socio Economic Status; M- Media Influence); Cultural Dimension(CI- Cultural Institutions; PC-Political, Societal and Economic Cultures; PI-Personal Identity; W-Worldviews); (From [11] and [12]).

5.1 Heuristic Dimension

The first dimension of agents is heuristics, which they apply throughout the global process. Heuristics are reasoning strategies based on common sense suffering metamorphoses from the biological and cultural evolution of individuals [Wachinger, G., et al,2010], [Kahneman, D., et al., 1974]. But also derived from acquisition of knowledge by learning new strategies. Learning is a derivative of social interaction and new information updates which is processed and integrated in episodic memory. The greater the knowledge and experience with logical reasoning, the greater will be the use of heuristics that follow this type of methodology instead of intuition. Regardless the nominal value that heuristics can offer, they are in fact mechanisms of how agents select, storage and process exogenous stimuli coming from environment that interferes on magnitude of risk and respective mental representations. These may work temporarily, regarding the type of risk, beliefs or other patterns of conscious perception [Wachinger, G., et al, 2010]. It is observable that agents with certain beliefs have several restrictions in terms of heuristic paths. They don't formulate heuristics against their own beliefs. Agents, simple apply their own beliefs. Although, empirical research demonstrates people have common heuristics [Wachinger, G., et al, 2010]. In this sense heuristic dimension is transversal to all perception process and not focused in any specific step.

5.2 Cognitive Dimension

The second dimension refers to cognition. Cognition as it was described in [Wachinger, G.,et al,2010] and [Renn,O.,2008] has influence on agent heuristics. Knowledge, emotions and personal beliefs affects perception through heuristics or directly. Emotions have been associated to an important role in perception and in decision making [Damasio,A.,1994]. Emotions influence the balance between potential benefits and harms, overlapping sometimes the beliefs. Of course, given the inherent causes and consequences of risk. [Wachinger, G., et al,2010]. Consequently, influences mainly judges. Stigmas, like being recognised as having a bad reputation by society also influence perception by stimulating fears [Wachinger, G., et al,2010].

Stigmas for example, have more effect on the way agents collect external data. They tend to demand the data they want avoiding other data types.

Cognition rules the allocation of qualitative characteristics from a specific risk. It determines the effectiveness of these features in terms of magnitude of perceived risk and consequently on the acceptability [Slovic,P.,1992]. Agents can be more fearful on their reaction when they have less knowledge and individual experience about the respective risk [Wachinger, G., et al,2010]

Cognition assumes a important role in creating expectations about the risk that an agent will face. It is also preponderant on selecting data and interpreting it.

5.3 Social Dimension

The third dimension, is related to social stimulus and interactions among people. It reports the level of trust in government and on institutions, which affects the way they perceive risk. For example, the perception of fairness and justice in the allocation of benefits and risks for different individuals and social groups. Fairness and justice have become more relevant to the perception of risk [Wachinger,G., et al,2010]. Another example is the power that some individuals have inside a group. So as reality, agent's tend to follow the mainstream. Social dimension affects fundamentally, the way an agent collects the data, influenced by media, institutions, opinion makers or even friends. We also note its presence on the trial step, where sometimes is decisive.

5.4 Cultural Dimension

The cultural environment is the fourth dimension and refers to cultural factors governing or co-determining the remaining levels of influence, described above. The "cultural theory of risk" supports cultural differences in risk perception and argues that there are four or five prototypes of responses to the risk [Douglas,M.,1992]. The specific preferences based on prejudice is a driving force for risk perception. Institutions assess risks according to their own vested interests and manipulate society in order to force it to accept them. Cultural factors are important because they generate values in agents. For example, familiarity with risk creates a culture of risk eliminating situations of stress. Typically, this familiarity helps agents to structure better the risk, comparing with other agents who don't

have this culture. Some agents are more methodical on perception process. Take the example of Germans or North Americans they generate methodologies to establish relations with risk in different types of activities or events. Instead Latin countries adopt and structured less the relation within risk. For Latin perception is more influenced by emotions from cognitive dimension or by power from social dimension. Another example is the influence of risk attitude which means the predisposition of agents to the risk. As is known, individuals from Nordic countries have less tendency to gambling in contrast to the Chinese. So their predisposition to the risk is lower than the predisposition normally presented by Chinese. In summary, cultural dimension affects selection of data, expectations and trial steps.
Each factor belonging to a specific dimension influences directly and indirectly each step of perception. Indirectly since factors at macro level affects factors in subsequent dimensions which in turn influence the steps of risk perception. It is also important to stress out that some dimensions or some factors can restrict the influence of other dimensions or factors. This means that some factors have contradictory or opposite effects. Meanwhile, it is important to highlight that not all factors intervene on perception. Everything depends from risk type and the context surrounding the risk event.

6 Discussion

The presented hybrid architecture has the intuit to fulfil an existent gap in literature for risk perception. As it was demonstrated risk perception is quite different from common perception, even if it uses part of subsystems of the brain. The fundamental goal is to establish a preliminary judgement in order to recognize the risk itself. Comparing this architecture with other architectures such COGNET, it is clear that this architecture goes beyond the representation of sensory components of perception. It demands the representation of more mechanisms involving risk perception, providing through this way more accuracy and precision to the representation of what really happens..
Other architectures establish that perception is more static and our objective is to supply an architecture that reflects the implicit dynamic existent on this cognitive process.
Unlike other architectures we defend that an agent must have capacity to reason and to react. And this capabilities work together and not separately as it was defended by other architectures. This architecture, rather than others has the capacity to represent correctly the competitiveness between reaction and reason on individuals mind.

7 Conclusion

Building an architecture for perception has been a challenge for the artificial intelligence community, with some successes, as was reported on this paper. Risk perception follows different pathways from physical perception and has some differences, independently of having in common some sensors. In this paper, we presented an architecture for risk perception that integrates its different steps with the respective dimensions that influence it. The proposed architecture falls within the group of hybrid architectures where sensors are the peripheral components and interpretation the main step where agents apply their reason. Memory is the data warehouse, a library of plans to act and a structure of intention.
This architecture can support different type of models, according to the risk type and context to be studied. Of course, this architecture is dynamic and it is open to the advances on risk perception.

8 References

[Freeman W.,1991] Freeman, W. The physiology of the brain. in Scientific American, Vol 264, (2) Pgs. 78-85, 1991

[Steel T, et al, 2010] T. Steel, D. Kuiper, R. Z. Wenkstern Virtual Agent Perception in Multi-Agent Based Simulation Systems IEEE, 2010

[Balcisoy, S., 2001] Balcisoy, S. Kallmann, M. Torre, R. Fua, P. Thalmann, D. Interaction Techniques with Virtual Humans in Mixed Environments. In International Symposium on Mixed Reality, Tokyo, Japan, 2001

[Herrero, P., et al.,2002] Herrero, P., Antonio, A. A Human Based Perception Model for Cooperative Intelligent Virtual Agents R. Meersman, Z. Tari (Eds.): CoopIS/DOA/ODBASE 2002, LNCS 2519, pp. 195–212, 2002.

[Chenney, S., 1996] Chenney Stevephen Sensing for Autonomous Agents in Virtual Environments, 1996 http://www.cs.berkeley.edu/~schenney/autonomous/sensing.html

[Tu, X., et al.,1994] Tu X. and Terzopoulos D., Artificial Fishes: Physics, Locomotion, Perception, Behaviour. Computer Graphics Proceedings of SIGGRAPH 94, pp 43-50, 1994.

[Terzopoulos, D., et al, 1994] Terzopoulos D., Tu X. and Grzeszczuk, R. Artificial fishes: Autonomous locomotion, perception, behaviour, and learning in a simulated physical world. Journal of Artificial Life, 1, 4, 1994

[Pew, R., et al, 1998] Pew R.W. and Mavor, A.S. editors. Modelling Human and Organizational Behaviour: Application to Military Simulations. National Academy Press, Wash., D.C. pp.200, 1998.

[Rasmussen, J., et al., 1982] Rasmussen, J., Lind, M., "A model of human decision making in complex systems and its use for design of system control strategies" Risø National Laboratory, DK-4000 Roskilde, Denmark April 1982

[Das, S., et al, 2000] Das, S. K. Grecu, D. L. COGENT: cognitive agent to amplify human perception and cognition. Proceedings of the Fourth International Conference on Autonomous Agents, June 5-7, 2000, Barcelona, Spain.

[Wachinger, G., et al, 2010] Wachinger, G & Renn, O (2010): Risk Perception and Natural Hazards. CapHaz-Net WP3 Report, DIALOGIK Non-Profit Institute for Communication and Cooperative Research, Stuttgart

[Renn,O., 2008] Renn, O. Risk governance. Coping with uncertainty in a complex world. Earthscan, London, 2008.

[Slovic, P., 1992] Slovic, P. Perception of Risk Reflections on the Psychometric Paradigm. In Krimsky, S, Golding, D, ed. Social Theories of Risk. Praeger, Westport, 1992, 117–152.

[Douglas, M., 1992] Douglas, M.. Risk and Blame: Essays in Cultural Theory. London: Routledge,1992.

[Damasio,A., 1994] Damasio, A., Descartes' Error Emotion, Reason, and the Human Brain, Penguin Group (USA), Inc., 1994

[Kahneman, D., et al., 1974] Kahneman, D. , Tversky, A Judgment under Uncertainty: Heuristics and Biases, *Science*, New Series, Vol. 185, No. 4157., pp. 1124-1131, 1974.

[Breakwell, G., 2007] Breakwell, GM. The psychology of risk. Cambridge University Press, Cambridge, 2007.

[Card, S., et al, 1983] Card, S., Moran, T., & Newell, A. The Psychology of Human-Computer Interaction. N.J., Erlbaum. 1983.

[Goldstein, B. 2009] Goldstein, e. B. Sensation and perception. Cengage learning,2009.

[Becker, J, et al, 1999] Becker, J. T., Morris, R. G. "Working Memory(s)". *Brain and Cognition* 41: pp 1–8, 1999.

[Georgeff, M.,et al., 1989] Georgeff, M.; Igrand, F., "Decision making in an embedded reasoning system. In:11th International Joint Conference on Artificial Intelligence, 1989 Detroit, Michigan, Ames Research Center,1989

[Russel, S. et al.,1996] Russel, S., Norvig, P. Artificial Intelligence: a modern approach New Jersey, Prentice Hall, 1996

[Alvares,L., et al., 1997] Alvares, L., Sichmam, J., "Introdução aos Sistemas Multiagentes" Jornada de Atualização em Informática, 16, Brasília UNB, 1997

[Bratman, M. et al, 1987] Bratman, M.; Israel, D., Pollack, M., "Toward an architecture for resource- bounded agents", Stanford University, 1987

[Mora, M. et al. 1998] Mora, M., Lopes, J., Coelho, J., Viccari, R., "BDI models and systems: reducing the gap" , Agents theory, architecture and languages workshop, Springer Verlag, 1998