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A Perceptual Meta-model based on the Ontology of Mental Models

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Abstract:

Studying the process of perception, various definitions can be achieved that each poses general steps of this process. In this paper, perception is tried to be broken down into smaller processes and consequently propose a meta-model to describe this cognitive process as a three-layer design including sensory perception, logical perception, and meaning perception. Considering mental model which explains thinking functionality in human, a two-way connection can be generated between perception and mental model, and then the nature of this connection will be surveyed so that a different mental model will be proposed for each perception layer. In addition, behaviors (outputs) will be described as they are based on mental models resulted from perception layers. After all, the proposed model will be developed through studying the Elementary Loop of Functioning (ELF) and perceptual processes will be described based on this adaptation.

Keywords: Perception, Meta-model, Mental Model, Elementary Loop of Functioning.

1. Introduction

To design an agent with the human-like cognitive abilities, it is necessary to recognize mental mechanisms generating such abilities. Mind is a complex phenomenon built on the physical scaffolding of the brain (Danielle S. Bassett & Michael S. Gazzaniga, 2011). Since, its functionality comes out of interactions between the physical level and multiple cognitive processes operations; mind is considered as a complex system containing variable and dependent components connected with each other so that its behavior cannot be concluded merely from components' behaviors (Joslyn, C & Rocha, L, 2000). Also, this point should be considered that specifying these components and how they communicate are quite vague. For a better understanding, complex system can be defined in different scales generally and in details. To facilitate surveying and clarification of mind's functionality, it should be decomposed into separate components of cognitive processes. Therefore, in this paper, perception is analyzed as the first complex cognitive component (Matlin & Margaret, 2009) which can be simplified through representing its main functionalities. For this purpose, by presenting a conceptual model in form of a collection of related concepts reflecting major elements of the phenomenon, and via removing some details, the complex process of perception can be simplified for a better understanding. So that main attributes and their connections between, will be posed in the conceptual model while some information will be overlooked through simplification. Hence, what remains is completely in association with the model's ultimate objectives (Touraj Baniroostam, Kamal Mirzaie & Mehdi N. Fesharaki, 2012).

Human knows the world around through receiving sensory information and processing them to meaning information. Perception is the mental process doing selection and organization, sensory information and meaning them dynamically (Bernstein & Douglas A, 2010). Based on researches, perception can be considered as a process from sense to act and classify its functionalities in a layer form which information is being processes in a particular way in each layer so that a mental model is built in order to recognize the world around within generating a pattern from the environment and processing that. Such pattern is a representative from the outside reality to understand surrounding world. Moreover, there is a two-way connection between perception and mental model. For a better understanding of this connection, definitions of perception and the ontology of mental model have been studied and their functionalities in different steps have been analyzed and finally as the result, a meta-model has been presented.

Accordingly, different definitions of perceptions have been presented in the second section and steps considered for each of these definitions have been studied. According to previous sections' discusses, in the third section the process of perception will be breaking down into smaller layers and the connection between perception and mental model will be proposed as a meta-model based on presented ontology. Finally, in the fourth section, the reference ELF model will be surveyed, the perception meta-model will be adapted on that and thereby, a developed model will be presented based on ELF.

2. Definition of Perception

Perception is the organization, identification, and interpretation of sensory information in order to represent and understand the environment (Schacter & Daniel, 2011). All perception involves signals in the nervous system, which in turn result from physical or chemical stimulation of the sense organs (Goldstein, 2009). For example, vision involves light striking the retina of the eye, smell is mediated by odor molecules, and hearing involves pressure waves. Perception is not the passive receipt of these signals, but is shaped by learning, memory, expectation, and attention (Gregory & Richard, 1987), (Bernstein & Douglas A, 2010). Perception involves these "top-down" effects as well as the "bottom-up" process of processing sensory input. The "bottom-up" processing is basically low-level information that's used to build up higher-level information (i.e. - shapes for object recognition). The "top-down" processing refers to a person's concept and expectations (knowledge) that influence perception (Kate Ellis & ccht, 2014), Perception can be split into two processes (Bernstein & Douglas A, 2010) Firstly processing sensory input which transforms these low-level information to higher-level information (e.g., extracts shapes for object recognition). Secondly, processing which is connected with person's concept and expectations (knowledge), and selective mechanisms (attention) that influence perception. Perception depends on complex functions of the nervous system, but subjectively seems mostly effortless because this processing happens outside conscious awareness (Goldstein, 2009).

We take in information through all five of our senses, but our perceptual field (the world around us) includes so many stimuli that it is impossible for our brains to process and make sense of it all. So, as information comes in through our senses, various factors influence what actually continues on through the perception Process (Susan T. Fiske & Shelley E. Taylor, 1991) that there are 3 step involved:

- i. Selecting
- ii. Organizing
- iii. Interpretation

Selecting is the first part of the perception process, in which we focus our attention on certain incoming sensory information (A Primer on Communication Studies, 2012). Attention is the behavioral and cognitive process of selectively concentrating on a discrete aspect of information, whether deemed subjective or objective, while ignoring other perceivable information. Attention has also been referred to as the allocation of limited processing resources (Anderson & John R, 2004).

Organizing is the second part of the perception process, in which we sort and categorize information that we perceive based on innate and learned cognitive patterns. Three ways we sort things into patterns are by using proximity, similarity, and difference (Stanley Coren & Joan S. Girgus, 1980). Although selecting and organizing incoming stimuli happen very quickly -and sometimes without much conscious thought-, interpretation can be a much more deliberate and conscious step in the perception process.

Interpretation, the final step of perception, is the subjective process through which we represent and understand stimuli. Interpretation is the process through which we represent and understand stimuli. Once information is organized into categories, we superimpose it onto our lives to give them meaning. Interpretation of stimuli is subjective, which means that individuals can come to different conclusions about the exact same stimuli. Subjective interpretation of stimuli is affected by individual values, needs, beliefs, experiences, expectations, self-concept, and other personal factors (Source: Boundless. "The Perceptual Process." Boundless Management. Boundless, 2015). Interpretation is the third part of the perception process, in which we assign meaning to our experiences using mental structures known as schemata. Schemata are like databases of stored, related information that we use to interpret new experiences. We all have fairly complex schemata that have developed over time as small units of information combine to make more meaningful complexes of information. Schemata are like lenses that help us make sense of the perceptual cues around us based on previous knowledge and experience (A Primer on Communication Studies, 2012).

In psychology, perception is being broken down into five steps or processes (DeVito, 2009):

a. Stimulation

Stimulation is the step, which the senses are being stimulated when information are perceived. Various stimuli come into effect base on individual's sight, smell, taste, touch and hearing (Devito, 2009).

b. Organization

In the step of Organization information is picked up by the senses and being organized. There is three ways in which perception is being organized. Firstly, by rules, secondly through schemata, and thirdly scripts (Devito, 2009).

- i. Organization by Rules: Proximity (if things are close to each other, they go together, for example, two people walking side by side down the street), similarity/contrast (people who look alike are related) and good form (even if a piece of something is missing, you treat it as a whole) (DeVito, 2007).
- ii. Organization by Schemata: definition schemata is the plural of schema, and is preferred in comparison to plural schemas (Devito, 2009). These are mental templates used to classify information. In general, it is the concept individual forms about things around them. Through the information collected daily; including past data residing in our memories after being sorted out with mental templates or structures.
- iii. Organization by Scripts: These are similar to schemata except they focus more on events and sequences and how things should unfold or play out (i.e. football game) (DeVito, 2007).

c. Interpretation-Evaluation

Interpretation-Evaluation: a linked term due to the association between the two processes. It can be greatly affected by experience, needs, wants, values, expectations, physical and emotional state, gender, and beliefs of how things should be, including the step organization (Beebe, Beebe & Redmond, 2002 & DeVito, 2007)

d. Memory

Memory stores information after undergoing steps of stimulation, organization and interpretation-evaluation. Nevertheless, information is not constantly stored, due to the accumulated impressions of past correspondence and association with things. Hence, information or details may be lost or distorted easily when they are dissimilar or a mismatch with what is already in our memory. On the other hand, information that is consistent with our schema will strengthen our ability to store them and is more resistant to changes (Aronson, Wilson, & Akert, 2002).

e. Recall

Recall: Memory is not reproductive, it is reconstructive. Based on your schema and scripts, you take the tagged elements to recreate what happened previously (DeVito, 2007).

3. Layers of Perception

Done researches on perception shows that this complex process is performed through different stages and a layer can be considered for each step. In some definitions, perception is broken down into two levels (Bernstein&Douglas A.2010) so that in the first one, information is superficially processed and in the second step, the process of allocating meaning to the sensory information is done. However, some other scholars divide perception into three processes of selecting, organizing, and interpretation (Schacter& Daniel, 2011) while in psychology, perception is being broken down into five steps or processes, including stimulation, organizing, interpretation, evaluating, memory, and recall (DeVito, 2009). Considering all mentioned definitions, a Meta-model of perception can be illustrated simplifying that into smaller processes as following:

- Physical senses
- Sensory perception
- Logical perception
- meaning perception

Five senses are the tool of communicating with the world outside and perception process begins with receiving information via sensory receivers which then are stored by sensory memory (Atkinson, R.C& Shiffrin, R.M. 1968). Senses are directly connected to the central nervous system, including brain and spinal cord and that is the way a perceptual communication is generated with the perceived things. In the first layer of the meta-model, sensory perception happens through the action of selecting so that electing is done on what generally received as choosing a part of that. Here the focus is on whatever sensed. After getting considered, information enters from the sensory memory to the working memory. After this level, selected part enters a level of perception which in, some effects will be remained inside the mind, even after losing the connection between the sensory memory and the sensed things. Then this part will be set into the active memory and in this level, processes are done in form of organizing patterns called proximity, similarity, and difference on sensory perceived data. These patterns are the same cognitive processes applied as analogy and reasoning (Induction, Deduction, and Abduction) which their function is performed in form of comparison, using similarities, moving from specific observations to broader generalizations, reaching the more general to the more specific and combination of mentioned functions to get the final result. These processes are considered as the layer of logical perception which in details of received information is extracted. In the other word, selecting attributes takes place in this level. After passing this step, information enters a level which in interpretation is done in form of allocating meaning to aforementioned information. Here in this level, direct sensory connection with the sensed matter is removed and details are analyzed apart from the perceived thing so that selected attributes are evaluated based on experiences, schemata, values, beliefs, and knowledge stored formerly in the longtime memory and after that will be interpreted as a meaningful whole and communications will be also reorganizing based on new meanings and ultimately extracting attributes is taking place as generating new attributes. Moreover, schemata are a pattern of experiences organized together in the same format. In case of correspondence of this scheme with the considered perception, it will be absorbed in the same structure and format and if there is no schemata corresponding that, adaptation will take place. Therefore, it means that a new structure is formed and stored as a new experience. This operation happens in the layer of Meaning perception.

Considering presented definitions, this can be said that one of the results of perception is generating mental model (Johnson-Laird& P.N. 2005) that this is the explanation of human thinking process about how the world is which can be considered as a pattern of the surrounding world, representative of the connections among the elements, generating new logical connections and building new concepts from the whole. In studying mental model, its ontology is discussed regarding to different definitions of that presented in different fields and consequently, some concepts will be extracted so that the nature of this phenomenon can be considered as a collection of words and concepts describing its existence. Extracted concepts can be mentioned in formats of Perception, Memory, Reasoning, Experience, Background Knowledge, Planning, Schema, Meme, Judgment, Optimization, Evaluating, Conceptualization, Adaptation and learning (Somayeh Mohammadi, Hayedeh Saberi& Touraj Baniroostam, 2015). Figure 1 shows the presented ontology of mental model.

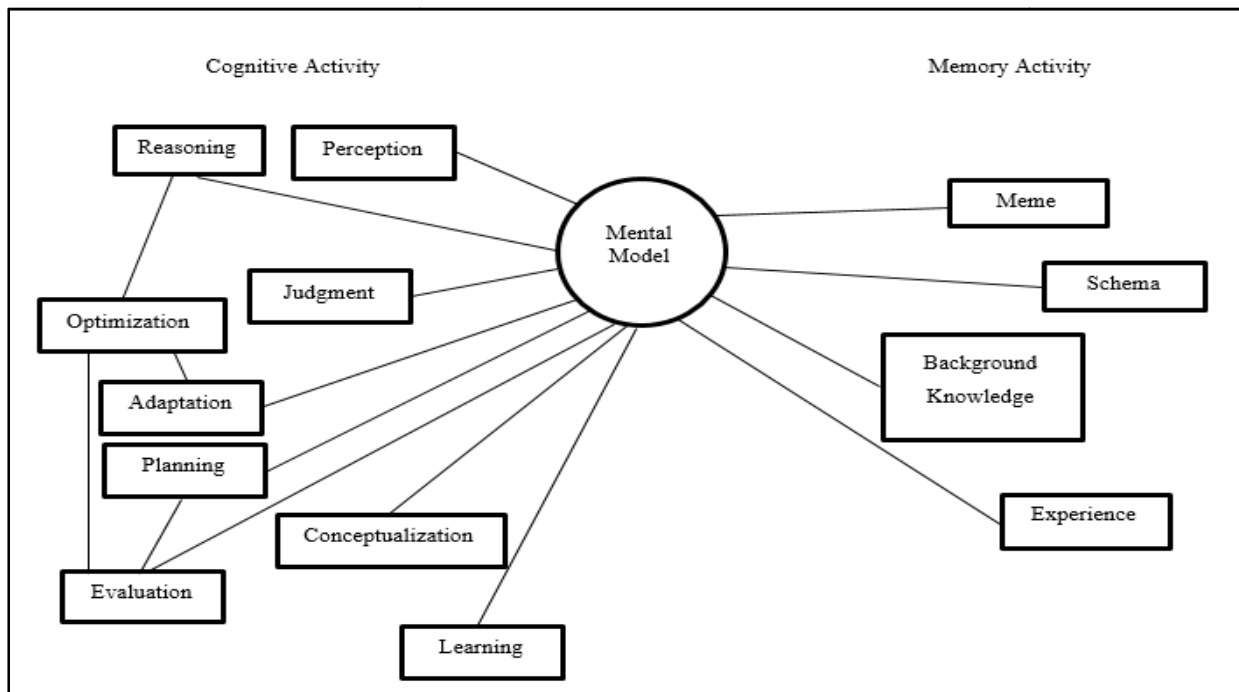


Figure 1: Ontology of Mental Model (Somayeh Mohammadi, Hayedeh Saberi & Touraj Baniroostam, 2015)

Since mental models can be considered as a result of perception, a connection between those and perception is formed which appears in different ways in various layers so that in the first level mentioned as sensory perception, is a space acting as a cognitive map representing a plan of the space perceived through removing details and focusing on the objective. In the second level, perception is dominating what is perceived based on logical structure formed in the mental model and in the third level, perception of information passed through the two previous filters in connection with individual and social experiences and schemata and knowledge building up the structure of mental model, is evaluated and interpreted so that a conceptualization happens based on meaningful information. It should be considered that mental model is a dynamic one updating itself through its transactions with perception. Hence, based on above conclusions, a three layered meta-model can be designed as demonstrated in figure 2.

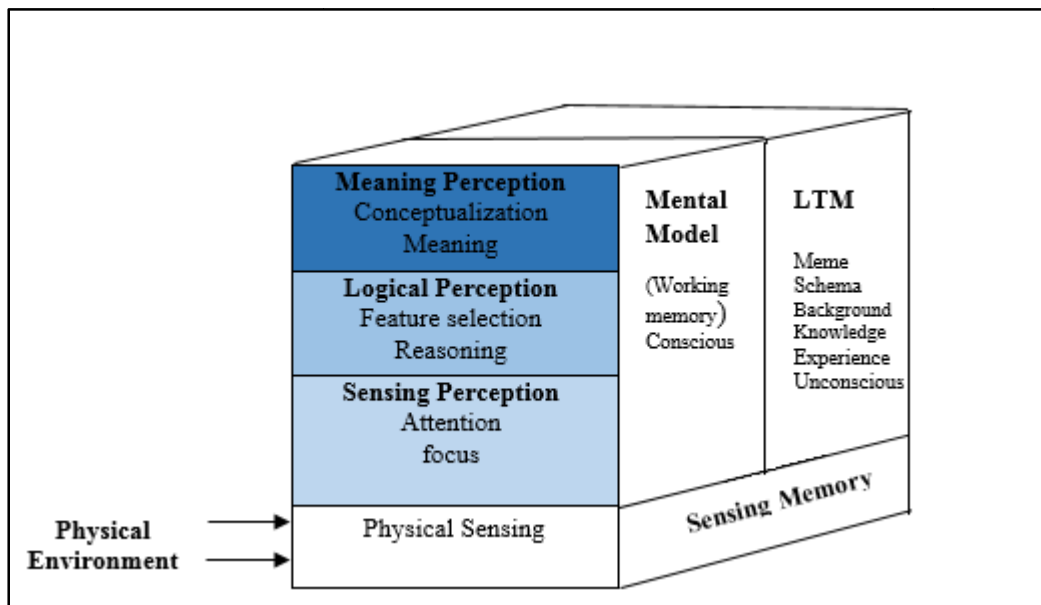


Figure 2: Meta-model of Perception

4. Developed Model of Perception

A complex process to be analyzed can be broke down into different levels considered as entities with elements in more simple connections. For this purpose, models having a reference framework can be used to describe, perceive, and specify noticed phenomenon. There are several other models with different approaches to perception so that to cover the distinction between them and the proposed meta-model through using Elementary Loop of Functioning (ELF) model, approaches to design a developed model of

perception can be considered to build systems able to do tasks similar to natural intelligent systems. ELF model looks at intelligence as a calculative phenomenon and it is said that systems with four main processes of sensory processing, world modeling, evaluating, and behavior generating can be considered to be intelligent (Meystel, Alexander M.; Albus & James S, 2001). The process of sensory processing has functionalities to focus, attention, recognition, and grouping attributes and features, comparison and specification. Modeling process builds and maintains events, entities, connections, and statuses. Evaluation process is about the level of importance, reward or punishment, and also the level of trust to what provided in world modeling ultimately leading to generating behavior. This model has been represented in figure 3 (A. M. Meystel, 2003).

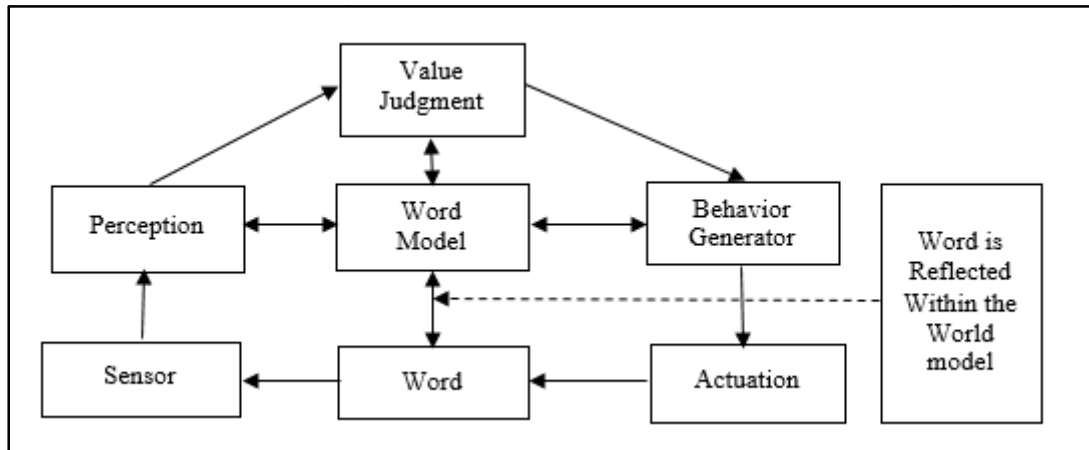


Figure 3: Elementary Loop of Functioning (ELF) (Meystel, Alexander M.; Albus & James S, 2001).

According to the operations done within sensory processing, it can be considered as the same as the perception in human. Five senses are the tool to connect to the world in person so that information is processed after being received by sensors. This operation takes place in different steps forming a loop which its result builds up a world model in the first step and repeating that loop with built pattern is compared and evaluated. Thereby, behaviors will be generated and updated based on the environment's reflection. After all, a developed model can be presented according to the proposed model of perception and surveyed definitions and also considering functional ELF. So that in terms of structure, a distinct mental model is designed for each level of perception and appropriate behaviors are generated for each one as well. Regarding to fig.2, sensory perception happens in the first level which mental model built based on that, can be considered as a mental mapping of the world outside and a centralized plan from the surrounding space. Furthermore, the behavior generated based on this model, is the most initial reflecting behaviors which are based on stimuli and response. In the second layer mentioned as logical perception, mental model is generated based on several kinds of reasoning making that to be considered as a mental model with loose connections since attributes of perceived things are extracted via logical reasoning and information becomes more and more detailed in order to describe the connections between perceived and the surrounding world. Therefore, the behavior generated based on this model can be considered to be of the logical type which means that the behavior is generated according to specified logical connections resulted from reasoning, deduction, induction, and abduction. Therefore in this layer, connections are based on appearance and in format of nominal information while the third level forms a mental model with stronger connections through building up meaningful connections between extracted concepts from previous layer based on stored concepts in mind in format of experiences and schemata. Consequently, the behavior generated in this layer can be considered to be rational so that meaningful connections are generated between information and their attributes and also a conceptual framework is shaped based on human experiences and knowledge in order to interpret the environment. In figure 4, a developed model of adapting functional ELF based on perception layers is proposed so that the three layers of sensory, logical, and meaning perception are set into ELF model and the representation of the surrounding word is illustrated as a mental model in three layers of cognitive map, mental model with loose connections, and mental model with strong connections which has a two-way connection with perception. After that, other processes are done such as data analysis, planning to reach favorable state to achieve the goals through organizing considered activities and ultimately, making decision as selection among alternative measures. At last, the process of behavior generation is shaped and applied on the environments through being transmitted to the actuators. It should be mentioned that evaluation is taking place during all these steps.

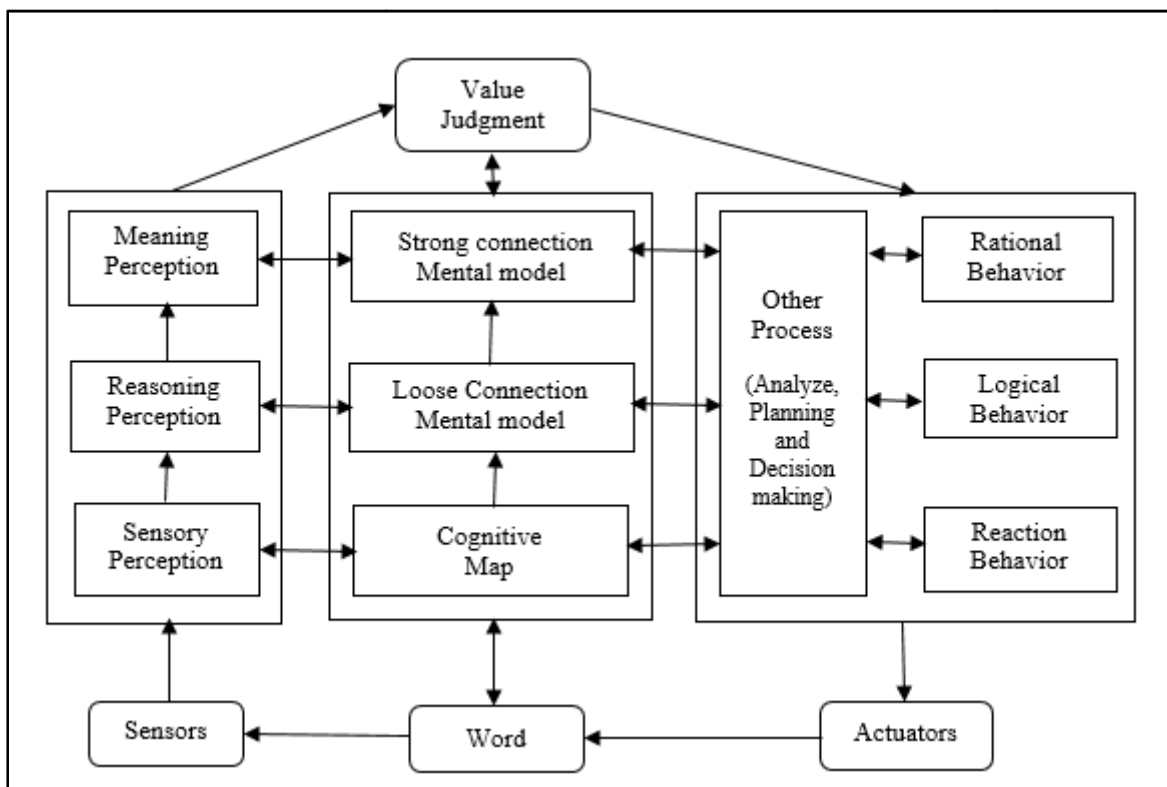


Figure 4: Development Model of Perception

5. Conclusion

Perception is a complex phenomenon done through different levels which to facilitate clarifying its functionality, some sub-processes with more details have been considered. Based on this separation, a meta-model including three layers of sensory perception, logical perception, and meaning perception is proposed and each layer's functionality has been described. Considering that mental models are generated as a result of perception, the connection between perception and mental model has been discussed based on related ontology. Then, regarding to correspondence of ELF reference model with the three-layered model of perception based on their mutual features, a framework has been provided and thereby, a developed model has been proposed so that perception results in generating a different state of mental model in each layer posed as cognitive map, mental model with loose connections, and mental model with strong connections. Therefore and after other processes, correspondent behavior have been generated and transmitted to the surrounding world through actuators. At last it should be mentioned that all human cognitive abilities in addition to mechanisms inside the brain have to be scientifically recognized in order to design and implement cognitive agents with perception process similar to human.

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