A Bidirectional Model for the Representation of the Interactions between the Organism and the Environment*

Isabel Barahona da Fonseca[1], José Barahona da Fonseca[2], Carmen Paz Suárez-Araujo[3], Armando Mónica de Oliveira[4], J. Simões da Fonseca[5]
[1] Faculty of Psychology and ES, Psychophysiology Dept, Lisbon, Portugal. Fax: + 351 21 7933408 Email: isabelbf@fpce.ul.pt
[2] Dept Elect Eng, Faculty of Sciences and Technology, New University of Lisbon, jbfo@fct.unl.pt, +351-214262406.
[3] Instituto Universitàrio de Ciencias y Tecnologías Cibernéticas. Universidade de Las Palmas de Gran Canaria, Las Palmas de G.C., Spain, cpsuarez@dis.ulpgc.es
[4] Faculty of Psychology and ES, University of Coimbra, Portugal, l.dinis@fpce.uc.pt.
[5] Faculty of Medicine, Sta. Maria Hospital University Clinics, Lisbon, Portugal.

Abstract
Aiming the delineation of a model for the interactions between organisms and environment the sensory motor transformations that occur in Posterior Parietal Cortex structures are used as a possible explanation for the contextualization of body representations in movement planning, command and execution. This is extended to the meaning construction in social interactions. A bidirectional model is proposed using script paradigm in which to each participant is attributed complementary generative functions and transformation operators of action/reaction. The interaction has a trajectory that unfolds in time of successive stages in which the criteria depend not only on the present conditions but also from future anticipated states which adds temporal and intentional dimensions to the model. The distance within this space of qualities determines the intensity and valence of emotions.
Keywords: Anticipatory self representation, Behaviour planning, Script paradigm, Emotion.

1 Introduction

From the point of view of psychological and psychophysiological theories it is accepted that the action of an organism on its environment depends upon "direct perception" - for Gibson (1984) a perception that is independent from propositional or associative internal representations. "Direct perception" guides action in an automatic and intuitive way. Numerous examples of this type of action regulation can be found in performance of acts of driving a car, arm and hand movements for reaching a goal object or else in movements for operating a device.

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"Direct perception" is linked to action and in its physiological organization depends on the dorsal visual stream. This kind of perception is distinct from the one that depends on the ventral visual stream. Namely it doesn't lead to representations that embody the enduring characteristics of objects and their relations or perceptual invariants but is linked to procedural processes.

The intentionality and the meaning of these perceptive data can only be found in the behaviour that they give rise: meaning and intentionality are pragmatic and are activated at a level inaccessible for declarative knowledge that links perception to motor action.

Assuming this perspective it is possible to deal with basic questions concerning the attribution of meaning and intentionality by the Nervous System (NS) reflecting on the transformations that allow the use of perception on control of motor acts - the sensory motor transformation.

It is hypothesized that such a functional process of transformation could be used in domains distinct from motor action - such as meaning construction in social interaction contexts.

2 The Internal World, the External World and the Intermediate Representations.

Internality / externality. From a subjective point of view the limits between internal and external experiences are clearly delineated. Nevertheless, from the point of view of performance of behaviours that involve actions directed to the external environment or the manipulation of devices these limits become fuzzy.

Gibson (1984) reflects that an object, say a pen that is on a table, is undoubtedly an external object. Although when it is manipulated in writing, during the action execution it is incorporated in hand's and finger preension schemata, articulation's movement motor schemata and also the postural adjustments necessary for writing.

In other words, an external object when it is manipulated from the action execution point of view becomes integrated in body movement schemata that allow its manipulation as if it was a prosthetic prolonging of the body.

That is, an object being external when it is utilized it is embodied in an internal sensory-motor schemata in which external references are integrated with movements' internal references in a way that don't respect the physical limits of both entities.

2.1 Different Types of Interaction with Objects.

The former example is a simple case where the operation of the artefact is strictly dependent upon operator's movements. Another kind of interaction is found in the operation of artefacts endowed with its own functions. Consider the case of the completely automatic ballistic missile, which lacks the possibility of an external modification of its behaviour and trajectory. The design of the aerodynamics, weight distribution and internal changes of the gravity centre together with launching conditions define its complete trajectory. Only the missile launching conditions depend on the behaviour of a human operator. Here, the behaviour is only intentional - the command of launching - for neither the missile movement nor its trajectory depend on anything else that the operator does or doesn't do. He only can activate the action, that once activated becomes independent from the will of the human operator. In what can be operationalities and commands under human control they are alienated on the missile design except for the initial conditions.

A special case of command's intentionality is also present in the operation of a microprocessor. The human operator can activate its internal routines that specify functions and also in this case the execution of functions doesn't depend on the human operator's behaviour but on programmed routines and subroutines that pre-exist its activation. This human operator command is only intentional and anticipatory. Intentionality is in the human operator and not in the structure that is operated that functions in a prosthetic relation with him.

Social interaction situations are distinct from the former ones. Here it exist a complex kind of interaction between the entities that is qualitatively different from the cases considered above: all the participants are endowed with equal possibilities for generating intention, signification and affective responses. Subjects actions occur in communicative social environment and are "interpreted" and activate actions/reactions of active others. So in a social context the subject can not anticipate completely the social consequences of his or hers actions. For predicting consequences the subject has to build a much more complex model than the one that were presupposed in former cases. It involves abilities to interpret others' behaviour in terms of their mental states (thoughts, intentions, desires and beliefs) and social and institutional rules, to interact both in complex social groups and in close relationships, to empathize with others' states of mind and predict how they will feel, think and behave.

2.2 The Sensory - Motor Integration.

In a sense the NS has to handle perceptive universals of external world arriving via sensory input structures. This information, processed and sometimes less processed, has to be converted in intentional behaviour: plans, commands and execution of motor output delivered back into external world. From the point of view of NS functioning using "direct perception" to guide behaviour poses a basic problem of integration of data from sensory systems – mapped in a system of coordinates specific for each sensory modality - with data adequate for motor system - mapped within a distinct system of coordinates, the movement coordinates. This transposition of systems of coordinates underlies the sensory motor integration.

As Llinas (2001) has proposed conceptually the area of transformation from sensory representation to motor representation is an "internal functional space" with qualitatively different properties from external world and yet, for motor output to have usefully expressed meaning, there must be a continuity of similarity: the internal space that is made of the functioning of neurons must represent the properties of external environment - it must some how be homomorphic with it. It is hypothesised that the internal space has transformational properties in order to provide homomorphic continuity between sensory derived properties of external world and subsequent motor representation and output. The question then lies in, acknowledging the differences in coordinate frames between the external and the internal worlds, understand how continuity between perception and execution can exist.

One idea is that these sensory-motor transformations are independent from specific coordinate systems. A simple example of coordinate system's independence is found in our abilities say to sign our name or draw a figure with our dominant hand, nondominant hand and also holding the pen between our teeth or between our toes. Perhaps the most important thing about all these productions is their high similarity although some muscle groups have more experience in translating a representation into action than others.

This means that the same internal representation can be externalised using entirely different motor coordinate systems - and if this happens to be the case, then the internal representation is transformed into motor execution space in a manner independent from the coordinate system.

The same can be thought about movements that are guided by perception, in the visual system, where it is known that the perceptual guidance of behaviour depends on the interaction between the ventral and the dorsal streams. As it has been proposed, the perceptual / cognitive systems in the ventral stream identify different objects in the external world - using a representational system that is rich and detailed but not metrically precise. That is, the ventral stream is "object based" and generates long-term representations of objects and their relationships. While the visual-motor mechanisms of the dorsal stream (in conjunction with related circuits in parietal, premotor, basal ganglia and brain stem) support actions directed to the object. In this case, the visual-motor transformations have to be viewer centred. In other words, both location, motion and also size of an goal object must be encoded relative to the observer in egocentric coordinates, that is retinocentric, head centred shoulder centred and so on. Further more as position and disposition of a goal object in action space of an observer is rarely constant this visual-motor transformation must take place every time an action occurs, that is, on line. The transformational algorithms applied to these inputs can be envisioned in the responses of a particular region of the brain that has functions in the body representation - the posterior parietal cortex, although it cannot be excluded the functional contributions of prefrontal cortex, basal ganglia and also hipoccampal formation.

It should be noted that at NS level the reciprocal connections between sensory systems and motor are multiple and occur at diverse levels of processing that are not exclusively posterior parietal. Fuster (1997) proposal of reciprocal connections at several levels of sensory (just beyond primary sensory cortex) and motor hierarchies should be mentioned.

2.2.1 The Body Representation and its Contextualization as Dependent from Functional Properties of Posterior Parietal Cortex Neurons

The cortical areas responsible for multiple NS sensory - body representations are located in parietal cortex where they are progressively represented and integrated in areas I, II (Brodmann area 5) and in posterior parietal cortex (Brodmann area 7). In each synaptic station beyond cortical somatosensory area I, the processing of messages referent to each body submodality segregated at peripheral receptors, streams and somatosensory cortical area I are successively integrated until in posterior parietal cortex body representations are integrated with other modalities sensory afferences that carry information about external world's places forward from subject, such as vision and audition.

The posterior parietal cortex is strategically positioned in the neighbourhood of somatic sensorial areas I and II but also of vestibular, visual, audition areas and has reciprocal connections with prefrontal cortical regions - such as premotor cortex and motor cortex.

Empirical data supports the hypothesis that the functions of posterior parietal cortex are functions of the kind just mentioned above: the transformation of external object reference coordinates system into body centred reference coordinates in a format adequate for generating motor plans and commands.

The posterior parietal cortex neuron's response depends upon direct convergence of sensory messages originated in teleceptors that are able to modulate the cell response to its body centred receptive field. In once, the cell's activity represent some aspect of internal world and also of the external world. In some way its sensory response is contextualized as if it was a neuronal answer that represents the self in its relation to external stimuli that are important for motor action. In this sense the neuronal sensory response is simultaneously intentional and anticipatory for it occurs in relation to sensory messages originated from goal objects / body parts important for the planning and future the execution of an intended behaviour that hasn't already occurred.

Empirical observations concordant with this hypothesis are found in Andersen et al. (1998) data about the response of posterior parietal neurons that have visual receptive fields but which response amplitude is modulated by eyes position. In other words, the cell's receptive retinotopic field gain depends on the eyes' position. These neurons could be used for generating visual receptive fields centred in body of premotor and putamen neurons. Furthermore, posterior parietal cortex projects to superior colliculus and ocular frontal field (brain areas that regulate saccadic eyes movements). In many cells of these regions is observed an activity that precedes saccades and that can be attributed to parietal aferencies.

These neurons' functional response can be though as a parallel at neuronal level of the fuzzy limits between internal and external worlds where the physical border is transposed incorporating external objects in internal body sensory-motor schemata. An interesting psychological - psychophysiological parallel in agreement with the Gibson's proposal mentioned above.

2.2.2 Motor Representation, Motor Imagery and Mental Training in Sports.

It has been supposed that in planning stages of motor control the brain builds an internal model of the action to be executed. Indirect evidence about the existence of a motor internal representation comes from sports' mental training effects where it seems that motor imagery leads to an improvement of motor performance in trained athletes. That is, in a trained athlete, physical skill can sometimes be enhanced by rehearsing the task in imagination

The exact process by which this performance improvement is achieved in mental motor imagery stills a matter of debate. Motivational, memory and other factors' influences cannot be excluded. But some argue that in motor imagery actions some processes are shared by overt and imagined actions. This hypothesis was based on the observation that involuntary movements frequently occur when imagining actions. Empirical studies of short term memory for discrete actions of Hall et al. (1995) have shown that performing a motor task during the rehearsal interval reduces the memory span in considerable way which in accordance with the idea that from a functional point of view, imaginary practice and physical practice share some processes.

3 Sensory Motor Processes as a Paradigm for Symbolic Cognitive Operations

As we have proposed elsewhere, the sensory motor schemata integrate sensory experiences with motor schemata that are intentional. The use of schemata with an intentional organisation, either implicit or explicit, proves the existence of cognitive operations that guide the action that aims at reaching a goal through complex hierarchical sequences (J. Simões da Fonseca et al., 1999).

We can use these sensory motor processes as a paradigm for cognitive operations that are organised in a symbolic representational system directly linked to sensory and motor information processing. Although these symbolic representations are accessible to a declarative and verbalizable knowledge, in its own the cognitive act of generating symbolic representations remains implicit and non-accessible to consciousness. In this way conscious thinking stays as a result of an action in its self non-conscious as it also were the cognitive integration between motor decisions and sensory afferencies.

The generation of intentional behaviours is not the result of a conscious process that can be translated into the linguistic declarative system, in so far that the decision is unconscious and implicit. Although execution occurs under implicit control, its resulting acts are constituted at conscious level and possible object for a conscious appraisal.

In our proposal these reflections are integrated in script's grammar (J. Simões da Fonseca et al, 1999).

The elements that constitute the script consist in initial conditions and the successive stages that presides execution. The subject, in each stage has available information about its internal world, about action and also about the world's environmental characteristics relevant for behaviour.

The transition from one stage to the successive depends on attainment of satisfaction criteria for this stage.

It should be noted that attainment of stages' satisfaction criteria is associated with a positive affect - an approach goal positive affect that is elicited as a subject moves closer to a goal. Phenomenologically these affective states refer to potential future outcomes as are anticipated, but the emotional experience it self occurs in the present.

Difficulties, unexpected from the point of view of initial script, can be created by environmental conditions - and in this way the attainment of satisfaction criteria can be compromised.

Said in other words, the valence and intensity of effective reaction depends upon the distance within a space of quantified entities from desired final goal, criteria specifications just achieved or failed and its possibilities of transformation.

The conditions of difficulties in attainment of satisfaction criteria generate a negative affect and subjects will attempt to reduce future negative emotions while he or she is experiencing unpleasant anticipatory emotions and hopes to cope with them.

In these circumstances an inferential procedure will specify the conditions that will permit surpass these difficulties and allow the attainment of satisfaction criteria in an interaction between decision rules that orient the subject's action and the reaction of environmental agents.

In any stage of processing these scripts dispose duple mechanisms of control: the initial script and a second mechanism of control that leads to the production of new data that either directly, either indirectly through an inferential process contributes for the specification of interaction characteristics - that become ostensive through an inferential process.

At the level of logical models, this inferential procedure involves a signification and intention calculus and the definition of new matricial operators that act on transformed functions.

3.1 A Logical Model for the Representation of Intentional Interaction with Environment

The use of symbolic notation about intentional interaction could be understood as a process which involves subject's decision rules, decision rules that depend on environment and that activate reactions and also any generative process that produce sequences of reactive stages (Figure 1).

The subject disposes a group of rules for acting on the environment (which aim modifying the conditions) and disposes also, within a limited range, of modifications of those rules that could be used and imposed during the interaction with the environment.

It could be also attributed to the environment generative rules - considered as a complementary system that intervenes in a cooperative (or else conflictual) way on subject's actions. The same is to say that the environment acts using a group of decision rules that in some way are similar to subject's decision rules: the state variables of each system in successive stages of interaction processing and also its associated satisfaction or else rejection criteria.

In each stage of an interaction the subject go through successive states (the space states: $S_k, S_i, \ldots, S_n$).

To each stage of interaction, S_n, corresponds a state of both subject and environment systems

$$S_n=((P_n, u_i, v_j) , (Q_n, u'_n, v'_n)) \qquad (1)$$

in which u_i denotes environmental variables relevant for subject's action specification, v_j the environment reactions and P_n subject's decision rules characteristic of each stage n and the environment system characterized by Q_n decision rules which occur in simultaneity with P_n.

The generation of successive stages S_i is specified by application of rules P_i and its complementary Q_i on variations of u and v.

This process consists in a trajectory of stages S_n in with its subject's generating rules P and associated environment reactive process Q suffers a transition to the state S_{n+1} produced by τ transformation:

$$\tau S_n = S_{n+1} \qquad (2)$$

There will exist a characteristic function for the final state that is desired by the subject

$$S'_{n+k}=F_{i,n} (S_n) \qquad (3)$$

And also reactive functions that satisfy the intentional structure of the environment that is compatible with subject's intentions.

If condition $S'_{n+k}=S_{n+k}$ is satisfied then the subject concludes the stage $n+k$ and goes to the next stage of interaction and experiences a positive affect that is anticipatory and anticipated in it self.

All the process is characterized by concurrent computation involving P_i and Q_i state functions and their transformation rule τ_i with its associated final criteria defined by (3).

This concurrent computation could be thought as a special case of mutual control involving not only the attainment of final criteria, but also the trajectories defined following intention.

In case of final criteria (3) is not attained and on the contrary the incompatibilities of environment reactions are satisfied, than operator τ will be modified allowing the essay of new decision rules expressed by functions P'_i and Q'_i.

In case there will be repeated failure and impossibility of goal attainment, an inferential procedure will produce a new group of hypothesis.

To each one of these hypothesis it will correspond principles with new decision rules that will lead to new state functions P'' e Q'' that can be obtained deductively. These new decision rules will be introduced in the process and in the same stage it will began a new operation cycle aiming at f attainment and avoid g.

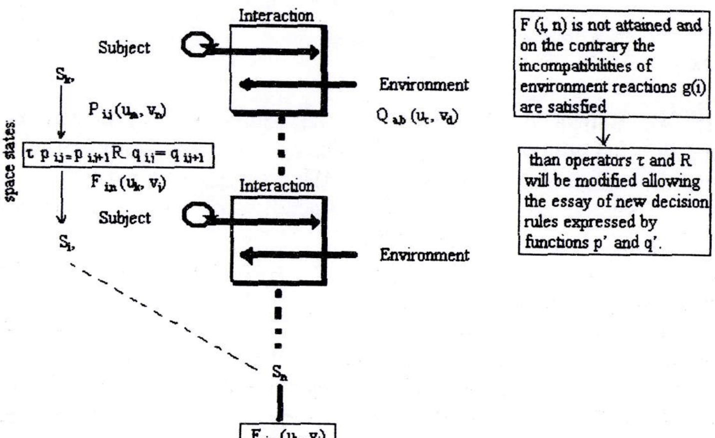

Figure 1: This figure aims at representing the logical model for the interaction between the subject and the environment.

4 Conclusion

Using some examples we tried to reflect that psychological functions such as self concept, meaning and intentionality can be envisioned as constructed in a anticipatory system in accord to Rosen's definition as "a system containing a predictive model of itself and/or of its environment, which allows it to state in an instant in accord with the model's predictions pertaining to a later instant". These representations in it self, are accessible to conscious thinking and can be communicated in a verbal form but in what concerns the processes of generation they depend upon non conscious processes – only the initial conditions, intermediary and final results are accessible to consciousness.

Neither are physical boundaries between internal and external worlds clearly delimitated in what concerns sensory motor schemata, neither is time in the sense that in psychological processes the time reference is distinct from its physical metrics. Namely, in what concerns human subjects' affective responses, planning and other processes that are linked to meaning and symbolic construction of the representation of events, time reference is hyperincursive in a sense that although phenomenological experience occurs in the present, in it self and in its generation it depends upon past experiences, present states and future expectations and anticipations.

The relevant process is characterize by paradoxical generation of self reflexive declarative utterances by non control implicit processes as well as by the generation and control of implicit processes by declarative cognitive processes as if the implicit programs the declarative and the declarative programs the implicit without any awareness of the command and control of the processes that build a thinking which is apparently completely conscious.

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