# Intentionality of Strong Anticipation in Motor Behaviors

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**Abstract**

Pezzulo (2008) and Grush (1997, 2004, 2007) highlight, even insist, the role of representation and internal models in anticipatory systems, in contrast to the role of adaptivity in the so-called 'mere adaptive systems'. The present paper argues against their claim, by alternatively arguing that the strong anticipation—anticipation without employing internal models—is primordial in the making of the anticipatory behavior, while internal models are supplementary in the light of efficiency. A novel notion of intentionality is raised for strong anticipatory behaviors, based on the history of on-line adjustments. The supplement of internal models on the top of a strong anticipatory system makes the resulting anticipatory system a Popperian machine, and consequently more flexibile.

**Keywords:** Weak and strong anticipation; internal models; intentionality; motor behaviors.

## Introduction

The embodied and situated approach to cognition is a general revolt against the representationism, the thesis that cognition consists of representations. This thesis is challenged radically by the behavior-based robotics (e.g. Brooksian robotics, Gibsonian theory of vision) and dynamic systems approach to cognition. Wherein, the role of agent-environment interaction is highlighted in the making of cognition, and the notion of cognition without representation is radically raised. Within this approach, however, some contend that the role of representation should be preserved (Clark 1997, 2003; Keijzer 2001; Grush 1997), as is manifest in Clark's notion of action-oriented representation. Later on, within the same approach does the need of representation scale up in the study of anticipatory systems. The role of representation (or, internal models) in such systems is highlighted, or even insisted, in contrast to the role of adaptivity in the so-called 'mere adaptive systems' (Pezzulo 2008; Grush, 1997, 2004, 2007). Model-based anticipation, thus, is seen as contrasted with adaptivity or reactivity, as is technically manifest in the contrast between weak and strong anticipation (Dubois 2003; Stepp and Turvey 2010).

According to Dubois (2003), anticipation is the determination of current states by taking account of future states. Weak anticipation predicts the future states with *models* of agents and the environment; whereas, strong anticipation predicts future states without such models. The strong anticipation employs the *system* itself (i.e. the agent and its immediate environment),[1] rather than an internal model (of agents and the environment). The role of models in anticipatory behaviors is well noticed (Pezzulo 2008)[2], as anticipatory behaviors are maintained control with internal representations. By contrast, the role of strong anticipation seems to be underestimated. In fact, strong anticipation needs more study (Steep and Turvey 2010). That is, the role of adaptivity in the making of anticipation remains in need of research.

In what way do motor activities bear an intentional relation to the environment? This query is a bit hard to answer. The motor activities, on the one hand, are clearly not managed by thought. Nevertheless, such activities, on the other hand, do not seem to be completely meaningless, as manifested in a query of Wittgenstein's: 'When I raise my arm, my arm goes up. And the problem arises: what is left over if I subtract the fact that my arm goes up from the fact that I raise my arm?' (Wittgenstein 1953, 1, paragraph 621). Motor activities, later, are considered in Merleau-Ponty's (1962) notion of *motor intentionality* as activities that are between reflexes and deliberate actions (Kelly 2000). Such activities, as Merleau-Ponty describes, are controlled by "a motor power, a 'motor project' (*Bewegungsentwurf*), a 'motor intentionality' in the absence of which the order remains a dead letter (Merleau-Ponty 2006: 126-127)". But, the question remains as to what this "motor power" is. If it is something that makes motor activities intelligent, then the question, further, would be twofold. The first is a 'what is' question: what is it that makes motor activities intelligent? The other question relates to the way in which the term 'motor intentionality' can make sense: can that motor power be understood with a certain sense of intentionality? Those two questions have been responded since the end of the last century.

Regarding the first question, the topic of motor control is well noticed both in psychology (Kawato 1999; Jeannerod 2006; Desmurget and Grafton 2000, to cite only three) and in philosophy (Christensen and Hooker 2002; Clark 2002; Clark and Grush 1999; Dreyfus 2007; Grush 1999, 2004, 2007). Motor activities are well conceived of in terms of anticipatory agents, emulators, feed forward models and feedback loops, etc. Regarding the second question, it has

[1] A slogan in favor of the strong anticipation is that the system itself is the best model (Stepp and Turvey 2010).

[2] Pezzlo (2008: 179) understands anticipatory behaviors in terms of internal representation: "we argue that the ability that characterize and defines a true cognitive mind, as opposed to a merely adaptive system, is that of building representations of the non-existent, of what is not currently (yet) true or perceivable, of what is desired", and … "[a] real mental activity begins when the organism is able to endogenously (i.e. not as the conquence of current perceptual stimuli) produce an internal representation of the world in order to select and guide its conduct goal-directed: the mind serves to coordinate with the future."

for long been conceived (as aforementioned in the notion of motor intentionality) that to account for motor activities would there be a sense of intentionality, which is very different from Brentano's notion of intentionality, a notion based on a standing-for relation that is typically adopted in the orthodox AI. However, two recent accounts attempt to re-affirm the importance of the standing-for-based intentionality in explaining anticipatory behaviors. The first, Grush (1999, 2004, 2007) maintains a difference between representational anticipation systems and adaptive systems. He highlights the role of internal representation in emulators—standing in for the actual motor activities—without discussing whether there is another sense of 'representation' (in other words, vehicle of intentionality) that can explain motor behaviors. The other, Pezzulo (2008) advocates the role of internal representation in explaining the guidance of goal-directedness in the anticipatory behaviors. Common in Grush and Pezzulo are two proposals: firstly, the contrast between truly cognitive minds and mere adaptive systems; and secondly, explaining cognitive mind/systems in terms of internal representations of the *non*-actual activities. A system with such internal representations, which can vanish before they are actually carried out, is called a Popperian machine, as Popper (1996) says that it can "let its hypothesis die in its stead" (cited from Pezzulo 2008: 195).[3] That system, in Pezzulo's (2008) term, is a system that can act on its representations instead of acting on its reference. Here, being a Popperian machine is taken as a requirement of a system's being cognitive.

The present paper argues for the three-fold primordial role of strong anticipation in the making of the anticipatory behavior. As we will see in the following sections, the strong anticipation is made possible by means of agent-environment coupling and system's (internal) states, while the weak anticipation by means of modeling. Firstly, the strong anticipation is primordial in the making of the anticipatory behavior, while internal models are supplementary in the light of efficiency. It is strong anticipation rather than the internal models of the system that makes possible anticipation. Secondly, a novel notion of intentionality, in contrast to that on the basis of the standing-for relation, is raised for understanding strong anticipatory behaviors: the relation in which the internal states of a body *brings about* a pre-registered end-state in the environment. On grounds of that novel sense of intentionality, strong anticipatory systems are intentional, apart from its being intelligent. Thirdly, the supplement of internal models on the top of a strong anticipatory system makes the resulting anticipatory system a Popperian machine, which is qualified to be a full-blown cognitive agent. The present paper puts discussions in the context of motor activities.

[3] A similar point is put in terms of a Popperian creature (Dennett, 1995, p. 375)—a creature capable of breaking their cycle of direct interactions with the local environment (Clark and Grush, 1999).

## Anticipatory Behaviors

### Internal Models

Reaching movement is a simple but paradigmatic example of the anticipatory behavior. The inverse internal models provide the feed forward motor commands that are necessary to bring about the desired trajectory in relation to a goal (Kawato 1999). Thus, prior to the onset of the reaching movement is a motor plan assembled. In the course of reaching movement, the motor plan is updated continuously by internal feedback loops. Internal feedback loops are employed because the biological mechanism of sensory feedback loops produces significant delays (Kawato 1999; Desmurget and Grafton, 2000). The internal feedback loops rely on forward models that integrate the sensory inflow and motor outflow to evaluate the consequence of the motor commands sent to a limb. The forward internal model predicts sensory consequences of issued motor commands (the probable position and velocity of an effector) with negligible delays, or even predicts them in advance. Thus, the forward models make the strategy of feedback loops efficient in the light of making a *real time* response for the reaching movement (Desmurget and Grafton, 2000). The representational status of anticipatory behavior is considered based on the importance of internal models, that make anticipatory behavior sufficiently efficient and accordingly make it possible in the ecological niche (Grush, 1997, 2004, 2007; Pezzulo, 2008).

### Strong Anticipation

An anticipatory system is a system that takes account of future states. A strong anticipatory system is an anticipatory system without employing an internal model; otherwise, it is a weak anticipatory system (Dubois 2003; Steep and Turvey 2010).

Steep and Turvey (2008) understands the notion of reaction in the sense that the determination of systems' states only takes account of current or past states, without considering future states. In this sense, homeostasis can be seen as reactive, as it is seen as involving no explicit goals at all. Examples of systems with no explicit goals are as follows: the single-cell *Euglena* approaching to the sunlight (Goodale and Milner2004: 40), a reflex, the Watt Governor (WG, van Gelder 1997), and the wall-following machine (Martaric 1990). The reflex as the resulting response is not pre-specified in the reflex mechanism of the muscle system. The WG is a device for the speed control. The state with a constant speed is the end-state, without being explicitly specified in the device. The end-state is an end-point of a purely physical chain. This makes the WG to be merely adaptive, although it is indeed an intelligent design.

By contrast, a thermostat, which is a goal-pursuing machine, embraces an explicit goal that is regarded as a pre-fixed state. The explicit goal is to be compared with a current state, and an error to be reduced is consequently derived. In addition, the outfielder discussed in Steep and

Turvey (2008) has an explicit end-state—catching the flying ball.

The strong anticipation preserves a role contributing to flexibility of motor behaviors. Such a role is two-fold. On the one hand, a strong anticipatory system approaches to the goal in the complex environment. For example, by lining up with the flying ball that becomes a fixed point (Clark 2003), the outfielder is likely to catch the ball successfully. On the other, the motor controlling system, as a strong anticipatory system, can further connect to various inner models and consequently makes the system at stake a *weak* anticipatory system. The former one, that achieves the goal, is the primary concern of an anticipatory system. Whereas, the latter, that is supported with inner models, makes the anticipatory system a Popperian machine and consequently more effective and efficient. As to the effectiveness, avoiding some likely impediment and thus making the way to achieve the goal more likely to success. As to the efficiency, it makes the way of achieving the goal passing various real-time constraints.

## Adaptivity in Strong Anticipation

This section considers two remarkable ways of adaptivity appearing in strong anticipatory systems: coupling and sensory feedback loops.

### Coupling Ensures Completing a Task

The agent-environment coupling, as considered previously in the example of an outfielder, ensures the completion of a task. When such coupling arises, a task would be accomplished effectively and efficiently. Consider the aforementioned outfielder problem. When the outfielder moves to a position where the trajectory of the ball is seen to be a point heading toward him, the coupling arises, and catching the ball is straightforwardly ensured. The accomplishment of the task is sometimes determined by that coupling condition.

In addition, coupling is inherent in the Gibsonian theory of vision and action. Visual affordances of an object, say, a cup, provide opportunities of actions, for example, grasping the cup. Consider the simple tasks consisting of single actions, such as the outfielder's catching the ball as aforementioned, and the task of grasping a cup. A coupling relation arises between the affordances of an object and the consequently provided action. As the visual affordances provide opportunities of an action, the coupling relation ensures the completion of a corresponding task.

### The Sensory Feedback Control for the *System*'s Performance

The sensory feedback control need *not* rely on an internal model,[4] if the efficiency of motor movement is not taken into account. The former part, the role of the sensory feedback control, is based on the dual model theory of motor movements, according to which a motor movement begins with a motor plan that rapidly transports the hand near to the target, and then depends on sensory feedback loops that slowly direct the hand to the target. The latter part, the non-efficiency of the sensory feedback control, is evident in the remarkable delay resulting from the sensory feedback control (Desmurget and Grafton, 2000). By contrast, a feed forward model, as manifest in emulators (Grush 2004), is an internal model that provides a simulation of motor actions. Based on a simulated motor action, when compared with the target, an error is derived internally.

To be noted, the derivation of an error and the following behavior of getting closer to the target on the basis of the sensory feedback control, is managed by the *system* without recourse to internal models. By contrast, the *internal* feedback loops (as opposed to the sensory feedback loops) rely on a forward model that makes the feedback strategy efficient enough for the real-time reaching movement. The resulting efficiency can be understood as it is a Popperian machine. However, as will be argued in next section, the *intentional* relation of the reaching movement is basically manifest in the system with sensory feedback loops, if we can provisionally put the consideration of efficiency aside. Such sensory feedback loops unfold on account of the system's actual activities and the sensory feedback control. The sensory feedback control of the system (as opposed to a model), hence, is primordial in the making of the motor control. The agent's way of relating to the target turn up primordially in the system's feedback loops.

## Intentionality of the Strong Anticipatory System

Do strong anticipatory systems bear intentionality? If they do, in what sense are they intentional? Let us put discussions in the context of motor movement. Such questions relate to two considerations. For the first consideration, such a notion of intentionality, if there is, seems to have something beyond the standing-for relation, given that motor movements are not completely thought-like. The goal-state is brought about as an end-state of a *causal* chain.[5] The question, more specifically, concerns the sense of intentionality which is born by causal activities. Then, the second consideration is that the motor movements, if they indeed bear intentionality in any sense, should be distinct from physical reactions. This section discusses the above two questions, centered on the notion of the goal.

[4] An internal model is a model of the system, including the agent and its immediate environment (Dubois 2003). A remarkable example is emulators (Grush 2004). The term 'internal' is contrasted with 'external', including the system as an embodied agent and the environment.

[5] An end-state of a motor system is a state specifying the way in which the target relates to its environment and the body.

### An Account of Pragmatic Intentionality

To respond to the first consideration, a novel notion of intentionality—pragmatic intentionality—is raised: an agent's motor activities bear intentionality in the sense that internal states of the agent's body *bring about* an end-state explicitly pre-registered in her perception or perceptual imagery. If we consider how it is possible that those internal states could bring about a specific end-state of a causal chain, then we need to understand the evaluative nature of the goal. The end-state is taken as the goal on grounds of evaluation. There should be discrepancies marked as negative values against states away from it, and there should be machinery of reducing such negative values. Thus, pragmatic intentionality can be further characterized: internal resources (such as sensory feedback loops, bones and muscles, energy, etc.) of an agent's motor system evaluate the discrepancies between the current state and an explicitly pre-registered end-state of the motor task, and reduce those discrepancies with the result of bringing about that end-state in the environment.

The involving motor activities are authentically intentional, as the agent with its body's internal resources cashes out an explicitly pre-registered end-state in perception or perceptual imagery by bringing it about in the environment. Those bodily internal resources transform the pre-registered end-state in perception or imagery into an end-state in the environment, an end-state consisting of inter-relations between the body, the target object and their environment. This is a pragmatic sense of intentionality because internal resources of the body are *used for* bringing about a pre-registered end-state. As a note, the above consideration has nothing to do with an internal model with a standing-for relation. As an example, a thermostat has pragmatic intentionality as it consists of a feedback model in relation to a pre-registered end-state.

To respond to the second consideration, the present paper highlights the role of the aforementioned pre-registered goal-state in the motor system. The end-state of the motor processing initially turns up in perception or perceptual imagery, and later is registered in the motor system before the motor processing unfolds. This pre-registered status makes the motor processing be neither physical nor reactive. It promotes the processing of the motor system from the physical level to an intentional level. To be noted, the goal has a two-fold role in the motor system. Despite the standing-for status of the goal, it does not stand on its own as an internal model (such as an emulator) of the motor system. The goal has a standing-for relation as it is initially marked in the perception or perceptual imagery. Yet, once it is pre-registered as the end-state of the motor processing, it stands in the *causal* relation to states of the motor system. A goal, hence, can be a part of a strong anticipatory system. This two-fold role based on the pre-registered goal-state in the motor system makes the motor system be neither purely physical nor completely reactive to environmental circumstances.

### A Primitive Shooting System and a Coaching System

A weak anticipatory behavior involves three elements: the system itself (or, agent), its environment, and internal models, while a strong anticipatory behavior involves only the former two elements. Consider the cognitive role of a strong anticipatory system, which is an agent in its environment. Let us discuss in the context of a premature shooting system supervised by a coaching system. Suppose that shooting system is capable of hitting the target with the probability of 10 % per shooting, that is, in average, hitting the target once in ten shoots. Let us further consider a shooting system with a supporting condition: the coaching system serves as a model that simulates the shooter's ten shoots, selects the best one, and accordingly the model draws the shooting system to the shooting conditions of that selected (best) one. Thus, the shooting system can shoot with 100 % accuracy in average. Such a shooting system is an anticipatory system, as the model suggests the shooting system on the basis of (simulated) future conditions.

Then, in theory, that shooting system would be capable of hitting the target accurately more efficiently. The aforementioned shooting system provides an analogy of an accurate motor system, in the sense that the internal model stands as a coaching system of the motor system.

One may contend that a motor system without the internal modeling is but a non-cognitive adaptive system like homeostasis. The coaching system is definitely cognitive, as it is a Popperian machine. Yet, a shooting system itself cannot be cognitive without the support of a coaching system. That the motor behavior is cognitive is because of the representing role of the internal models. [6] Such a representing role is that the internal models simulate and accordingly stand for the motor system together with its environment.

## Intentionality, Representation, and Decouplability

### The Intentionality of Anticipatory Systems

An anticipatory system can be seen as bearing intentionality, in the sense different from the Brentano's notion of aboutness—the traditional sense of intentionality. Note that intentionality is a relation between the internal states of a system and the world. Consider the reaching behavior as an example. The system directs the body of a robot or a biological body, such as limbs, to the target in the environment. The achievement of a goal, hence, cannot appear internally. Rather, it should take place with the real body of the anticipatory system in its immediate environment. The achievement of a goal should be controlled internally in the anticipatory system, with or without the support of an internal model. The internal states

[6] The theme of the present paper is intentionality, but not cognition *qua* cognition, hence the question of defining cognition is simplified.

of that system are dynamic, which may optionally be supported with internal models (as weak anticipatory systems). Let us discuss in terms of the control theory. In a strong anticipatory system, those internal states include the making of a motor plan (as an inverse model of the goal), sensory feedback loops (producing an error by comparing the current position of the hand and the goal), and the hand movement with a view to minimizing the errors. A weak anticipatory system, by contrast, is further supported with internal models. Both in the strong and the weak anticipatory systems, the internal states subserve the body in the light of reaching the target.

As a reminder, we previously made a pragmatic definition of intentionality for strong anticipatory systems. The goal-directed agent processes resources of an agent's internal states and uses them such that the agent's performance reaches an explicitly pre-registered end-state of processing. The goal-directed agent is qualified to be intentionality-bearing since the processing of internal states brings about performance in the environment. Note that the goal-directed action is made by the anticipatory *system*'s internal control (not by internal *models*). The internal control is manifest in the agent(hand)-environment coupling when the feedback loops are running. The internal control shows a tendency to reach the goal state.

How do the internal states of an anticipatory system work apart from the functionality of its internal models? In weak anticipatory system, internal models (e.g. emulators) represent the way in which the system will unfold in the environment. They represent on grounds of the aboutness relation, that the internal states of the system stand for the system's mechanisms and the environmental conditions. By contrast, apart from the internal models, the internal states of the anticipatory system *encode* the way in which the system manages to bring about the bodily reaching. How could the strong anticipatory system bear intentionality?

## Rowlands' Account of Representation in Deeds

The notion of strong anticipatory behaviors is closely addressed by Rowlands (2006) in terms of *deeds*: deeds consist of "an array of on-line, feedback-modulated adjustments that take place below the level of intention, but, collectively, promote the satisfaction of the antecedent intention (p. 103)." Rowlands claims that deeds are truly representational, where representation is characterized with the five conditions: (i) informational condition, (ii) teleological condition, (iii) decouplability condition, (iv) misrepresentation condition, and (v) combinatorial condition. Among them, what seems hardest to justify is the decouplability condition: "[i]tem *r* qualifies as representing states of affairs *s* only if *r* is, in an appropriate sense, decouple from *s*. The problem is that it seems to conflict with their *on-line* nature of feedback-modulated adjustments. Even if this problem is solved, a further problem is that simple adaptive devices, such as the WG, the thermostat, and homeostasis, would consequently appear to be qualified as representing.

Those two problems seem likely to be solved in Rowlands' justification of decouplability: the learning history of a motor system provides it with a proper function, which can run "off-drive" in the absence of environmental stimuli (p. 166). Repetitive practice of a motor action, say, catching a flying ball, results in a proper function of ball-catching. The inner states of the motor action are decouplable from the real stimuli of a flying ball, as such states can run in absence of those stimuli. The activating instances of a catching-ball device may differ while some of them might fail in a catching action. Yet, the learnt motor system has obtained the proper function of ball-catching.[7] In addition, animals can learn, whereas the WG, the thermostat, and a homeostatic system cannot. As a consequence, such adaptive devices cannot have a bearing of representing.

Rowlands justification of decouplability, however, assumes intentionality instead of explaining it, as it resorts to the history of learning (in his term, practice). The present paper would justify the aforementioned decouplability without recourse to either practice or learning, but, instead, relies on the history of the system's on-line adjustments. A successful catching system may operate on different objects, and may even fail in some instances; yet, it is truly a system that represents the states of affairs of catching-a-flying-ball. Such a behavior does not causally dependent on a specific kind of objects or events in the environment; hence, that motor system represents the capability of catching-a-flying-ball.

By contrast, the WG, the thermostat, and a homeostatic system, are not representing in the previous sense. The WG and the thermostat are (artificial) devices that do not retain a history of adjustments. In addition, a homeostatic system does not respond to the common living world, world in the literal sense. Here we preserve the term of representation to systems that are capable of responding to the common living environment. homeostatic systems may be perfectly anticipatory system; yet, it seems to stand at the nebulous boundary of representation that anticipatory systems have.

## Conclusions

The present paper explains motor intentionality, by arguing that strong anticipation is primordial in the making of the anticipatory behavior, while internal models are *supplementary* in the light of efficiency, like a coach supporting a baseball team. A baseball team can perform without a coach despite its lacking good strategies for winning.

The strong anticipatory system bears intentionality because it transforms itself from a body registering a perceptual or imaginary end-state into a body which realizes that end-state in the environment. Such an intentionality is pragmatic because internal resources of the body are used

[7] Rowlands deems that this way of justification is "all the decouplability we can reasonably require for the deed (167)."

for bringing about an end-state in the environment. The pragmatic nature of such an intentionality makes clear two components of the goal-directedness: an explicit end-state pre-registered in perception or imagery, on the one hand, and an evaluative sub-system and a machinery that reduces the negative values, on the other. The former component is put intuitively as a goal and the latter is machinery that brings about the goal in the environment. Thus, we can succinctly put the pragmatic intentionality of strong anticipation in terms of the relation of *bringing-about*, that is, internal states of the body bringing about the end-state in the environment. A novel sense of intentionality, in contrast to that based on Brentano's notion of aboutness, is characterized in terms of a system's history of adjustments.

A notable difficulty in considering a novel sense of intentionality for motor activities is the question of how to distinguish between motor intentionality and mere adaptivity. Both of them are put in causal chains; yet, the former is intentional, while the latter remains purely physical (or biological). To resolve this difficulty, the present paper resorts to the history of (on-line) adjustments in the systems' response to the real environment. This is a feature unseen in merely adaptive systems such as homeostasis, the Watt Governor, and single-cell *Euglena* approaching to the sunlight. They do not register their history of (on-line) adjustments, and accordingly are not anticipatory systems.

Motor behaviors are anticipatory. The present paper explains why and how they are representing, in response to the questions addressed by Wittgenstein and Merleau-Ponty, as mentioned in the introduction. The supplement of internal models on the top of a strong anticipatory system makes the resulting anticipatory system a Popperian machine, which makes the anticipatory systems more flexible. Because they are representing, the strong anticipatory systems discussed in the present paper are not 'mere adaptive systems' as conceived of by Pezzulo (2008) and Grush (1997, 2004, 2007). Internal models in the anticipatory systems are supplementary, although they are necessary in the light of efficiency that is manifest in efficient motor behaviors.

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