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Sensorimotor teleology and goal-directedness
An organismic framework for normative behaviour

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ABSTRACT: Teleosemantics explains meaning by appealing to the biological norms that make error possible, but most work in the field still anchors those norms in evolutionary "selected-effect" functions. We develop an *organismic* alternative grounded in the self-maintenance of autonomous systems. Building on sensorimotor theory and enactivism, we reconceptualise goals as second-order constraints—transient attractors in a dynamic sensorimotor field—and show how they are nested into a heterarchy of means–end relations connecting global self-maintenance of the sensorimotor organization and identity of a system with the most basic sensorimotor coordinations. Drawing on this framework, we identify the *minimal necessary* requirements for genuine teleological behaviour: 1. *Initiation* that individuates an action in relation to a goal, 2. *Modulatory execution* that adaptively compensates perturbations or deploys alternative strategies in relation to the goal, and 3. *Meaningful termination* through successful acknowledgment and transition, goal-sensitive persistence, or coherent abandonment. We locate *normativity and error* in the dynamic presuppositions among sensorimotor schemes and goals: failure manifests as incoordination within, or across, goal branches. We finally illustrate our account with a detailed analysis of the well known A-not-B error in psychology, showing how infants meet our teleological criteria while revealing incoordination as tension breakdowns inside a heterarchy of goals and sensorimotor schemes. Teleological behaviour, therefore, is the management of tensions and dynamic presuppositions within the goal heterarchy, not a chain of mechanical causes, thus delivering a naturalised notion of purposiveness that opens up an alternative route to teleosemantics beyond evolutionary selection.

KEYWORDS: Behavioural Norms; Teleology, Goal-directedness; Organizational Biology; Teleosemantics; A-not-B Error; Sensorimotor Normativity

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1. Introduction

Human understanding of reality is traversed by two broad categories of systems: those passive entities governed by natural laws, inner principles or external forces that determine their change over time, and those that direct themselves towards goals, bringing about their own will, desire, or intention into the explanation of their behaviour. This division (or the need to reconcile it) has puzzled philosophers for centuries. If we are not to accept a supernatural explanation that violates or subordinates the causal order of the first kind of systems, how are we to explain the emergence of the second type within the first? It is not a trivial question. A number of metaphysical and ethical questions pile upon it: How can future states (goals or desires) cause current events? Is there room for meaning in a world of pure events? How can we defend the claim that certain systems, behave according to their own-norms? Is free will and volitional action possible?

A characteristic feature of intentional behaviour is its normativity: the possibility to produce success or failure, to do well or bad, better or worse. However, normative descriptions are problematic in science, both in biology and in the cognitive sciences, and these puzzles go back to Kant's view on teleology and Brentano's position on intentionality (Neander, 2017; Rama, 2023). Science is factual. It explains how things have happened and seeks to predict future events. However, as soon as we enter the realm of the living, functional and normative explanations also seem to be necessary. While we do not describe planetary movements in functional and normative terms, it seems appropriate to say that a certain trait is not working properly, that behaviour is faulty, or that someone is mistaken. The problem of error arises, precisely, when we want to explain the adaptivity of living processes in teleological terms—whether cognitive or biological. The description of a system in these terms presupposes the system's goals could not be achieved. Teleological explanations must therefore allow for error, and intentional behaviour is a hallmark of teleology.

Fortunately, there are various theories of teleology and functionality. As might be expected, different teleosemantic projects emerge depending on the chosen theory of biological function. Classical teleosemantics (Millikan, 1984; Neander, 2017; Papineau, 1987), is based on the etiological theory of selected-effect functions (hereafter SETF; Ayala, 1970; Millikan, 1989; Neander, 1991b; Ruse, 1971), which defines the function of a trait as the effects of that trait during natural selection processes. Classical teleosemantics thus states that the processes that produce a behaviour must function according to their selection history during evolutionary processes.[3]

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[3] The selectionist foundation of teleosemantics has been extended in different directions, providing more refined definitions (Artiga, 2021), introducing other levels of analysis in selection processes (Garson, 2017), or enabling a pluralism of sources of biological functions (Shea, 2018).

This paper takes a different approach. It advocates an organizational theory of biological functions. In this sense, it preserves the core teleosemantic route but wants to contribute to the construction of *organismic teleosemantics*.[4] The reasons for this are twofold. First, the organizational view of functions has an important weight in current theoretical biology, in which several advances, conceptualizations, and empirical findings have been made in recent decades (Barandiaran, 2025; Christensen & Bickhard, 2002; Mossio et al., 2009). Thus, the organizational view is a solid proposal with a well-defined tradition and a particular perspective of the biological field (see Section 2). Moreover, there is a strong continuity between organizational approaches in the philosophy of biology and autonomous enactive approaches in philosophy of mind and cognitive science (Di Paolo et al., 2017a; Thompson, 2010). However, the analogy between the biological and the sensorimotor domains remains underexplored, theories of biological function are still to be fully transduced into the cognitive and sensorimotor domain, particularly on exploring the notion of teleology in goal-directed sensorimotor interactions.

The second reason is that the SETF and its adaptationist foundations are heavily criticized in the contemporary philosophy of biology---see Rama (Forthcoming) for an overview of this point. Some criticisms are explicitly directed against the SETF (e.g. Bickhard, 2004; Fodor & Piattelli-Palmarini, 2011; Griffiths, 2006; Newman, 2023; Rama, 2022). In other cases, the critics target the adaptationist foundations (e.g. Amundson, 2005; Gould & Lewontin, 1979; Lickliter & Berry, 1990; Reid, 2007) and different controversial assumptions of neo-Darwinism that are relevant to the SETF. Our aim here is not to present these criticisms, nor to provide new ones. But only to recognize that the door is open to the search for alternative attempts at teleosemantics. The organismic perspective offers an *intrinsic* source of normativity grounded in the precarious self-maintenance of autonomous systems (Barandiaran & Moreno, 2006; Christensen & Bickhard, 2002; Di Paolo, 2005; Di Paolo et al., 2017b; Jonas, 1966; Mossio & Bich, 2017; Weber & Varela, 2002), providing a *synchronic* alternative to the *historical* grounding of SETF. The incentive for organismic teleosemantics, in sum, is both the current relevance of the organism in biological theory and the limitations of classical teleosemantics.

The central aim is to establish the minimal requirements for characterizing teleological behaviour from an organismic perspective. This allows us to define the condition under

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[4] Here we discuss teleosemantics in a broad sense, to include every perspective of intentional behaviour. The word "semantics" is used as an "umbrella term" that intends to dialogue with the teleosemantic tradition. In this sense, our aim is to discuss the biological bases of teleosemantics beyond the SETF --- we specifically discuss the teleo side; i.e., we focus on how an alternative naturalist teleology can be applied to teleosemantics. However, as far as the semantic side is concerned, our aim is to provide a perspective on intentionality behaviour that could be useful for different positions on intentionality.

which the system can be said to have made a behavioural error. An important component that we add to the theory of autonomous systems is the characterization of behavioural goals as part of a meshed hierarchy (or heterarchy) of goals. Specifically, we will argue that understanding goal-directedness requires analysing the *nested heterarchy of goals* and the *dynamic presuppositions* inherent in sensorimotor coordination. This nested view is central to account for the normativity of teleological sensorimotor explanations. The consequences of behavioural errors are to be found in the relations between different behavioural goals and their relationship to sensorimotor coordination structures. To show how our proposal works, we will analyse a specific case study, the A-not-B error, where the minimal requirements are satisfied and the hierarchy of goals can be appreciated.

The paper proceeds as follows. In the next section, we outline the key conceptual elements of the organizational view of teleofunctions according to autonomous systems' theory. In Section 2.1, we begin with an introduction to biological norms from an organizational perspective. Next, in Section 2.2, we move to the cognitive level to introduce the autonomous view of sensorimotor normativity. Section 3 presents our specific contribution to teleology in this tradition. Section 3.1. explores the nature of goals in terms of second order normative constraints; section 3.2 introduces a hierarchical nested view of goals; section 3.3 provides a detailed set of minimal requirements for teleological behaviour, and sanction 3.4 revisits the issue of error and normativity in sensorimotor systems. Section 4 is devoted to analyse the A-not-B error as an empirical case study to which our previous definition of teleological behaviour is applied. We close in Section 5 by summarizing our proposal and identifying open questions for future works.

2. Autonomous Systems and Behavioural Norms

2.1. The organismic approach to naturalizing normativity

The organismic, enactive, or autonomous-organizational approach to normativity and teleology is not new. It finds its roots in Aristotle's biology, Kantian self-organization and its widespread effects on *Naturphilosophie*. In a more scientific context, it can be notably traced to the work of Claude Bernard (1865), Walter B. Cannon (1932), Kurt Goldstein (1939), with more theoretical and philosophical developments by Eduard Steward Russell (1945), Georges Canguilhem (1966), and Hans Jonas (Jonas, 1966). Cybernetic ideas (Rosenblueth et al., 1943; Wiener, 1948; Ashby, 1952, 1957) and System's theory (Bertalanffy, 1969) facilitated the formal characterization of some organismic intuitions to finally deliver progress in organismically inspired theoretical biology and psychology (Pattee, 1973; Rosen, 1972; Maturana & Varela, 1980; Kauffman, 1993; Piaget, 1969). More recently, autopoietic or bio-enactive approaches

(Di Paolo et al., 2017b; Thompson, 2010; Varela et al., 1991) together with complex system's approaches to theoretical biology and philosophy of biology (Bechtel & Richardson, 2010; Capra & Luisi, 2014; Kauffman, 2000, 2003; Moreno et al., 2011; Mossio & Bich, 2017) have further developed this trend. Particularly important for this article is the development of an organism-centered theory of normative function (Barandiaran, 2025; Christensen & Bickhard, 2002; McLaughlin, 2001; Mossio et al., 2009; Schlosser, 1998).

The fundamental difference between the organizational and the adaptationist or selected-effects account of teleosemantics is that the former is anchored on the *current* (molecular, physiological, behavioural) organization of the system to naturalize normative functionality. The notion of a self-maintaining organization of autonomous systems is central to this approach (Moreno & Mossio, 2015; Varela, 1979). Unlike rocks, tables, cars or clouds, living organisms are recursively self-maintaining systems: energy is needed to keep their dissipative structure stable, and it is channelled to produce constraints that sustain them as far-from-thermodynamic equilibrium systems (Nicolis & Prigogine, 1977). Some dissipative structures are relatively simple (vortices, oscillatory chemical reactions, convection cells, etc.), while living ones have more organized complexity and display self-producing capacities by which the very constituents of the system (its parts) are a physico-chemical product of the system they compose, while actively distinguishing themselves from their environments, e.g. through the generation of a membrane (Maturana & Varela, 1980; Ruiz-Mirazo & Moreno, 2004)[5].

The function of a trait or component process of an autonomous system becomes normative as it is *dynamically presupposed* by the rest of the organization for its continued maintenance: each element *X* of the system relies on the proper functioning of other elements of the system, as well as these other elements depend on *X*. The (proper) function of the heart is to pump blood because the rest of the body parts (liver, lungs, veins, etc.) presuppose the completion of the function for their own maintenance and that of the whole system (Christensen & Bickhard, 2002). Moreover, not only is the overall function fixed this way, but also the rate or specific functioning, i.e. the function of the heart is to pump blood at a certain rate. It is thus possible to envision a *virtual normative field* defining the rate of functioning or regulation of each component under different circumstances of the rest of the system: e.g. you need to breathe faster if you haven't done so in the last 2 minutes, or you can drink less water in the 5 hours if temperature is not high, and you did hydrate yourself properly during the last 2 hours, etc. (Barandiaran, 2025; Barandiaran & Egbert, 2013).

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[5] However see (Virgo et al., 2011) and (McGann, 2024) for a critical debate on this point

2.2. Sensorimotor norms

Metabolic and other physiological functions ultimately serve the organism's material self-maintenance, grounding biological autonomy (Maturana & Varela, 1980; Ruiz-Mirazo & Moreno, 2004). Beyond metabolism, Varela (1979)[6] recognised further autonomous closures—immune and neurodynamic—each with its own identity and self-maintaining conditions. In this section, we shall focus on the emergence and specificity of sensorimotor autonomous organisation, made possible by the development of the nervous mediation of agent-environment relationships, together with the development of muscular bodies capable of reversible movements in space (that in turn permit the emergence of reliable sensorimotor invariants, directionality, etc.)[7].

As a result of developmental processes, sensorimotor (SM) patterns get organized in increasingly reliable sensorimotor schemes (Arbib & Hesse, 1986; Merleau-Ponty, 1942; Piaget, 1947). In the enactive tradition these have been understood as sensorimotor contingency structures (Noë, 2004; O'Regan & Noë, 2001): behavioural units supported by environmental, bodily and neurodynamic structures (Di Paolo et al., 2017b). Behavioural, environmental and, importantly, neurological interdependencies exist between SM-schemes in terms of sequence transitions, modulation, consolidation, reinforcement, coherence, etc. This intricate mesh is itself a complex organisation that might be said to parallel or be analogous yet distinct to the biological one; while supported-by, embedded-in and functionally contributing-to it (Barandiaran, 2008; Barandiaran & Moreno, 2006, 2008): Also in terms of functionality and normativity. To say it with Piaget: "[K]nowledge comprises first and foremost an organisation function, and that is our first fundamental analogy with life. Any act of the intelligence presupposes the continuity and conservation of a certain functioning." (Piaget, 1971, p. 150). This functioning, for Piaget, is rooted in nothing other than sensorimotor coordinations, then abstracted into schemes that capture invariants and build an organized network of interdependent schemes: "cognitive functions constitute invariants which are vital to their functioning" (p. 150). How can behavioural or cognitive functionality and normativity be grounded in terms of their own "conservation"?

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[6] Maturana and Varela conceived the operational closure of the nervous system as a proper level of autonomy (in fact it was this level of closure that inspired its export to the autopoietic or metabolic level). But the tension between the closure at the level of neural dynamics and its further structural coupling with the environment, together with the development of embodied conceptions of integrated brain-body-environment dynamics, lead to some authors (Barandiaran, 2008, 2017; Barandiaran & Moreno, 2006; Di Paolo et al., 2017b; M. Egbert, 2018; Smithers, 1997), as we shall see, to conceive autonomy at the level of behaviour (including neural, but also environmental and bodily dynamics on the constitution of the closure).

[7] For a detailed analysis of this transition and the emergence of sensorimotor normativity in evolution and development, see Barandiaran (2008) and Barandiaran & Moreno (2008).

A single habit provides a basic sense of sensorimotor normativity (M. D. Egbert & Barandiaran, 2014; Mojica, 2021; Wake, 2009). Like a riverbed that facilitates the channelling of the water flow, that in turn carves down deeper the riverbed, that in turn channels the water…, basic habits are self-reinforcing, self-maintaining sensorimotor structures: the more they are enacted the stronger the support structures that bring them about (particularly neural and muscular ones but also the environmental ones that are often produced and reproduced by the habits themselves). Yet, a single habit is not an organized form of life, it resembles more a parasite than a proper subject. It is only when a complex web of habits emerges that an identity as such is constituted and that the complex interdependence of habits gives rise to global coherent viability conditions, that can ground a proper sense of sensorimotor normativity: "the specificity of cognitive dynamics [...] is given by a particular kind of dynamic organization within the NS [nervous system] and between the NS and the internal and external environment, i.e. the adaptive preservation of a web of dynamic sensorimotor structures sustained by continuous interactions with the environment and the body" (Barandiaran and Moreno, 2006, p. 180). This brings forth a concrete sense of normativity grounded on self-maintenance: "every enacted scheme in the network can have positive or negative consequences for the viability of the whole. The set of structural and functional dependencies between schemes defines the viability conditions for the ongoing maintenance of the sensorimotor network, very much like molecular self-individuation defines how food concentration, pressure, or temperature affect the viability of cellular life." (Di Paolo et al., 2017b, p. 154).

This analogy between biological and cognitive normativity can be strengthened through the notion of constraint closure (Montévil & Mossio, 2015) as a basis for functionality and teleology (Mossio & Bich, 2017)[8]. Most of neural constraints over electrochemical activity are also produced by sensorimotor dynamics (from neuronal architecture in development, to synaptic growth and strengthening/weakening through activity dependent plasticity), together with some bodily constraints like muscle memory, musculoesqueletal synergies, or elasticity. Also, environmental constraints that sustain sensorimotor organization are enacted (selected and structured through sensorimotor coordinations) and often actively produced (from spatial arrangements to the fabrication of tools or symbols). There are different types of such constraints, but one is normatively signified and plays a central role for a teleosemantic programme: the goal-directed behaviour that characterizes sensorimotor teleology. Moreover, as we are about to see, the nested organization of goals could be interpreted as some kind of closure of second-order constraints.

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[8] This is a first strong analogy with organizational accounts of biological normativity. But there are others: There are dynamic presuppositions (Barandiaran, 2025; Christensen & Bickhard, 2002) of how some constraints should operate for the sensorimotor flow to produce and maintain the other constraints that in turn sustain the whole.

3. Minimal Requirements for Sensorimotor Teleology

3.1. Sensorimotor teleology and the nature of goals

On the one hand, we have the general normative standard of self-maintenance of a behavioural identity as the ultimate system's goal. On the other hand, the myriad of sensorimotor schemes or habits that both contribute-to and define such a goal. A refined analysis of sensorimotor teleology requires depicting how intermediate goals connect SM-schemes with the most general goal of self-maintenance. But what is a goal that can be fixed or determined for a given behavioural scene, yet different to habits or sensorimotor schemes? How do they relate to each other?

It is possible to picture the emerging organisation as that of a network of SM *coordination patterns* (e.g. gaze-neck coordination), organized into *schemes* (e.g. walking down the road), structured into *strategies* (e.g. going to the grocery-story taking the shortest route or the safest one), which, in turn, are clustered into *activities* (e.g. shopping, hunting, cooking, grooming, etc.), and altogether compose the complete web of SM-schemes that constitute the behavioural *identity* of an agent, with some *regional identities* emerging in complex sociotechnical contexts (e.g. the professional-teacher, the family-parent, etc.). It is possible to envision different types of emergent normative constraints in behaviour that connect all these levels of organisation. Some of them might take the form of finalistic constraints ("achieve X", "do Y", etc.), others might be proscriptive ("do not fall down", etc.), others might be stylistic ("to do X in a certain way"). None of them need to be explicitly encoded. The notion of constraint[9] avoids taking norms to be, necessarily, antecedent mechanical causes, but understands them instead as emergent tendencies of self-organized dynamics (Juarrero, 1999; Kelso, 1995; Thelen & Smith, 1994). Teleological, finalistic, constraints are perhaps the most important way in which cognitive organisms both motivate and steer the multilevel organisation of behaviour through the structuring of goals.

Defining goals in terms of complex dynamical system attractors has a long tradition in philosophy (Heylighen, 2023; Juarrero, 2010), biology (Waddington, 1957), neuroscience (Braun & Mattia, 2010; Freeman, 2001; Ijspeert et al., 2013), psychology (Carver & Scheier, 2002; Kugler & Turvey, 1987; Van Orden & and Holden, 2002) and robotics (Schöner et al., 1995; Tani & Ito, 2003). More recently, and aligned with the view develop here, McGann talks about a "nested landscapes of attractors" (2007, p. 481) and Di Paolo et al. also briefly suggest

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[9] We depart from the definition of constraint as "a reduction on the degrees of freedom of the elements of a system exerted by some collection of elements, or a limitation or bias on the variability or possibilities of change in the kind of such elements" (Umerez & Mossio, 2013). Some constraints can manifest as an efficient causal limit (like the wall of a container or the catalytic effect of an enzyme) other like global emergent properties (like convection flows or transient attractors).

that "[w]e may also picture the temporal dynamics of the selection and activation of a scheme as the emergence and shaping of a particular basin of attraction in the agent's sensorimotor space" (2017b, p. 201)[10]. But adopting a generic dynamic stance is not enough to fully characterize teleology and goal directedness. If goal-states are simply attractors, there is no possibility of error, since any end state is, by definition, an attractor. Thus, an agent cannot be said to fail, for whatever the (failed) end state is, it has to be interpreted as the goal of the agent. The most extreme and ultimate consequence is that the primary goal of a living agent is to die. An additional problem with a raw equation of goal-state with attractor is that our experience teaches us that goals can be satisfied, and they dilute as attractors to make room for new goals. There are resources from dynamical systems theory to accommodate some of these problems. In fact, we need not talk about point attractors, but instead of transient attractors in heteroclinic orbits (Rabinovich et al., 2008), or chaotic itinerancy (Kaneko & Tsuda, 2003). This is, however, not the place to attempt a precise mathematical characterization of goals as dynamical entities, but to specify what are the *organizational morphodynamic propertie*s that such dynamical entities need to comply with, to become goals and constitute teleological behaviour.

A naturalized conception of such emergent constraints is to conceive the means vs. ends or current-state vs. goal relationship as a *tension*. In turn, this tension can be expressed as a field where the goal (finalistic normative constraint) is an *attractor*; or a proscriptive constraint a *repellor.*[11] Merleau-Ponty's notion of motor intentionality can be considered a forerunner of this conception, when he states that "(...) the task to be performed elicits the necessary movements from him by a sort of remote attraction, as the phenomenal forces at work in my visual field elicit from me, without any calculation on my part, the motor

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[10] Di Paolo et al. do not elaborate further regarding teleology, goal-directedness and attractor landscapes and focus instead on the networked relationship of co-activation and inhibition between sensorimotor schemes (an approach on top of which we have built ours). Also, unfortunately, McGann suggests this vision of the nested landscape of attractors just in the conclusions, without elaborating it further. Following Merlin Donald, he equates the basic type of sensorimotor teleology we elaborate here with operant conditioning and the "islands of rationality" it creates, focusing most of the paper instead on mimetic and mythic forms of cognition.

[11] The conceptualization of goals as attractors in a normative dynamical field raises a delicate question: must an attractor be achievable in order to function as such? While certain physical or biological attractors may be unreachable due to constraints of time, space, or feasibility, they may still exert a guiding influence on behaviour. Consider, for instance, the case of a migratory bird navigating towards a breeding ground that, due to unforeseen climate change, no longer provides the necessary conditions for survival. Even though the end goal (a viable breeding site) is no longer attainable, the bird's sensorimotor and navigational patterns continue to be drawn towards the historically relevant location. The attractor is thus not a fixed point in the landscape, but a dynamically embedded structure within the agent-environment coupling. Similarly, in the domain of human behaviour, an aspiring musician who dreams of performing at a now-defunct venue (e.g., a legendary concert hall that has been demolished) still orients their training and aspirations around that goal, demonstrating how attractors can remain active in shaping behaviour even when their physical realization is impossible. (Thanks to Matthew Egbert for raising this question).

reactions which establish the most effective balance between them". (Merleau-Ponty, 1944, p. 122). If the current state is the enaction of a specific SM-scheme (e.g. walking towards the fridge), and the enaction of a future SM-scheme satisfies the tension of the goal (e.g. grabbing a snack), this doesn't mean that the goal *is* the latter SM-scheme. It is instead the field that we need to take as the relevant causal unit of goal-directedness and the way in which this field of tension is structured and transformed; the meeting of the conditions of satisfaction of a goal being an important part of it.

Although the metaphor might break down at some point, we might be able to capture some relevant aspects of our approach by appealing to the different causal accounts at play on a ball rolling along a surface. The most widespread causal story to explain the movement of a ball is that something hit the ball, an antecedent event, triggering the motion of the ball. On a flat surface, all we need to know to explain and predict the movement of A is B's momentum and the time of the collision. But the triggering event and the surrounding causal conditions could be of a different nature. The event could be one that changes the inclination of the surface where the ball rests; which, in turn, could take different shapes. Unlike the preceding case, the force responsible for the ball's motion (gravity) was already present before the inclination changed. Once the inclination is set, the original event becomes irrelevant for predicting the trajectory—the ball moves according to the structure of the environment and the ball's momentum and friction.

An attractor is a stable state or pattern towards which a system evolves over time, within a range of starting conditions and possible perturbations. In this case, the ball's movement is not dictated by a sequence of causes, but rather by the topology of its environment: the ball "seeks out" lower potential energy states due to gravity. Now, to elaborate this idea further, imagine that instead of a simple incline, the ball is rolling on a curved surface with valleys and peaks. The ball will settle into a particular region depending on how the surface guides its motion. That final resting point (or cyclic pattern) is the attractor of the system—a state the system tends to evolve towards.

The situation becomes even more interesting if we consider that the ball is rolling not on a rigid surface, but on an elastic blanket—a surface that deforms under the ball's movement. In this case, the movement of the ball doesn't just follow a fixed landscape; it actively reshapes the very constraints that guide its motion. This is an example of a non-holonomic constraint—a constraint in which the system's future behaviour is influenced by its ongoing trajectory. This analogy extends to goal-directed behaviour When an agent acts, it does not simply move toward a predefined endpoint as if pulled by a static force. Instead, behaviour unfolds in a landscape of constraints that it simultaneously reshapes. Just as the ball deforms the elastic surface, altering future motion possibilities, an organism's actions transform its cognitive, social, and physical environment, restructuring the conditions that define its future actions.

Thus, goals emerge as higher order constraints as a result of local and contextual constraints, not as event-driven causes. They shape the conditions that guide behaviour, rather than act as discrete forces pushing an agent toward a particular outcome. The "teleology" of action is more akin to an attractor dynamically emerging from an evolving landscape of constraints than a pre-set causal endpoint. Note that the attractor exists nevertheless, it is possible to compute it in a simulation, but it doesn't pre-exist the ball and its movement, so to speak. Within this picture, we can also depict how environmental and agent-side (neural and bodily) support structures can modify the tensions on the elastic blanket (through clamps that grip the sheet from the sides or above, or through stakes that hold it up). More interestingly, goal-directed agency involves the capacity to fix, for a certain unfolding, a specific set of stability conditions (attractors) towards which the trajectories are robust and capable of overcoming perturbations and obstacles. Moreover, and this is a crucial point, as we shall see, once a stable equilibrium is reached (a goal is attained) the landscape is transformed. To be sure, we need to avoid the interpretation that a teleological goal-directed agent is the ball, the passive sufferer of constraints and forces. Instead, agency manifests the top-down wholistic constraining modulation that shapes its trajectory.

As a consequence of understanding goals as dynamic constraints, when we illustrate the whole sensorimotor organization as a network of SM-schemes, there would be no specific node that corresponds to self-maintenance. In fact, it would amount to a category mistake to identify a node with a goal of the SM-scheme, although the enactment of some sensorimotor schemes might instantiate the condition of satisfaction of a goal (and perhaps also the reinforcement of the SM-schemes that brought it).

It is thus important to distinguish between *two types of meshed relationships* in sensorimotor organization. On the one hand, we have the *SM-network* itself understood as potential transition networks between SM-schemes, themselves composed of SM-coordination structures, and composing activity networks (as developed in detail in Di Paolo et al., 2017b). On the other hand, we have a topology of tensions, a relationship between increasingly abstract goals that parts of the SM-scheme network can satisfy. We call it a *heterarchic network of nested goals.* To cook a meal, or to have a drink, are goals that can be satisfied in many different ways. To chop a tomato might be a component part of cooking a meal (but also smashing the tomato, or frying a potato) and to buy a soda can be necessary for your drink (but also finding a glass). In turn, both, chopping and shooting, can also be satisfied by different SM-schemes, the tomato can be chopped with different types of knives or cutting techniques, and shooting a prey can be carried out with different tools and methods, each involving different SM-coordinations, etc. But how do behavioural goals relate to one another and to SM schemes? How can we envision the organization of behaviour in terms of nested goals?

3.2. Nested goals and the organization of behaviour

Normative constraints do not operate in isolation. Nor of type nor of token. The architecture and electrochemical nature of neural activity makes holistic integration much more complex and intricate than any other organismic physiological functional decomposition (Anderson, 2016). The goal of drinking water as a channeling constraint of my current sensorimotor engagement with the world is not a fixed trigger of my behaviour. I am continuously balancing contextual opportunities and demands (both internal, external and relational). I don't just "want ginger-ale" I want it cold, but not that cold, I prefer it on this glass type, I want to have it in a specific temporal window (I can't wait 3 hours), I don't want it at any cost, I might prefer the iced tea I just saw on my fridge, I might delay it, but not too much, I might find a different way of satisfying my thirst or to welcome my guest (for whom that drink was meant as a mean of showing hospitality). *Goals appear nested on a meshed hierarchy, and that nesting is constitutive of their being the basis of teleological behaviour*. On the one hand, this nesting brings the whole behavioural organization, system identity and normative force to each specific action. On the other hand, every goal that we conceive as such is itself composed of smaller constitutive goals, until means-ends collapse into a single sensorimotor coordination. Figure 1 illustrates the relationship between the heterarchy of goals and the SM-network (for simplification, in Figure 1 we depict a hierarchical organization, see below for discussion).

In this vein, while the global self-maintenance of an organisation (in this case sensorimotor) can be defined as the main goal of autonomous systems, we can define further intermediate goals that contribute to it. Furthermore, each intermediate goal may also involve other "lower-level" goals, constituting a nested hierarchy or, most accurately, if we look at the tinkering and self-organized nature of living systems, a heterarchy (McCulloch, 1945; Bechtel, 2022). In order to provide a cleaner formal picture of our approach, we shall limit ourselves to a hierarchical structure as a particular case of a more general network or heterarchy. This is in fact a common assumption in the neuroscience of action (Grafton & de C. Hamilton, 2007; Uithol et al., 2012), psychology of goal-directed behaviour (Miller et al., 2013), philosophy of intentional action (Pacherie, 2008), and in robotic and agentic modelling (Ghallab et al., 2014).

The hierarchy therefore consists of different levels, as we advance in Figure 1. At the top, on level m, we find the main goal of self-maintenance of the whole sensorimotor organization. Self-maintenance requires various intermediate goals at the lower-level m-1. Goals on level m-1 can branch out into further goals on level m-2. In this way, we obtain a branching structure of goals organized at different levels of abstraction, where each node ramifies into alternative goals at the next level of abstraction. To generalize, at level n of the hierarchy, there are higher-level goals at level n+1 and lower-level goals at n-1 (see Figure 2). The relationship between levels can be understood as a means-ends relationship. Goals at level n-1 are the means to achieve goals at n, goals at n are the means to achieve goals at n+1, and so on. While global self-maintenance is the only level without higher-level goals, at the lowest level we find the raw sensorimotor coordination patterns (e.g. neuromuscular synergy of a microsacade) without lower-level means.

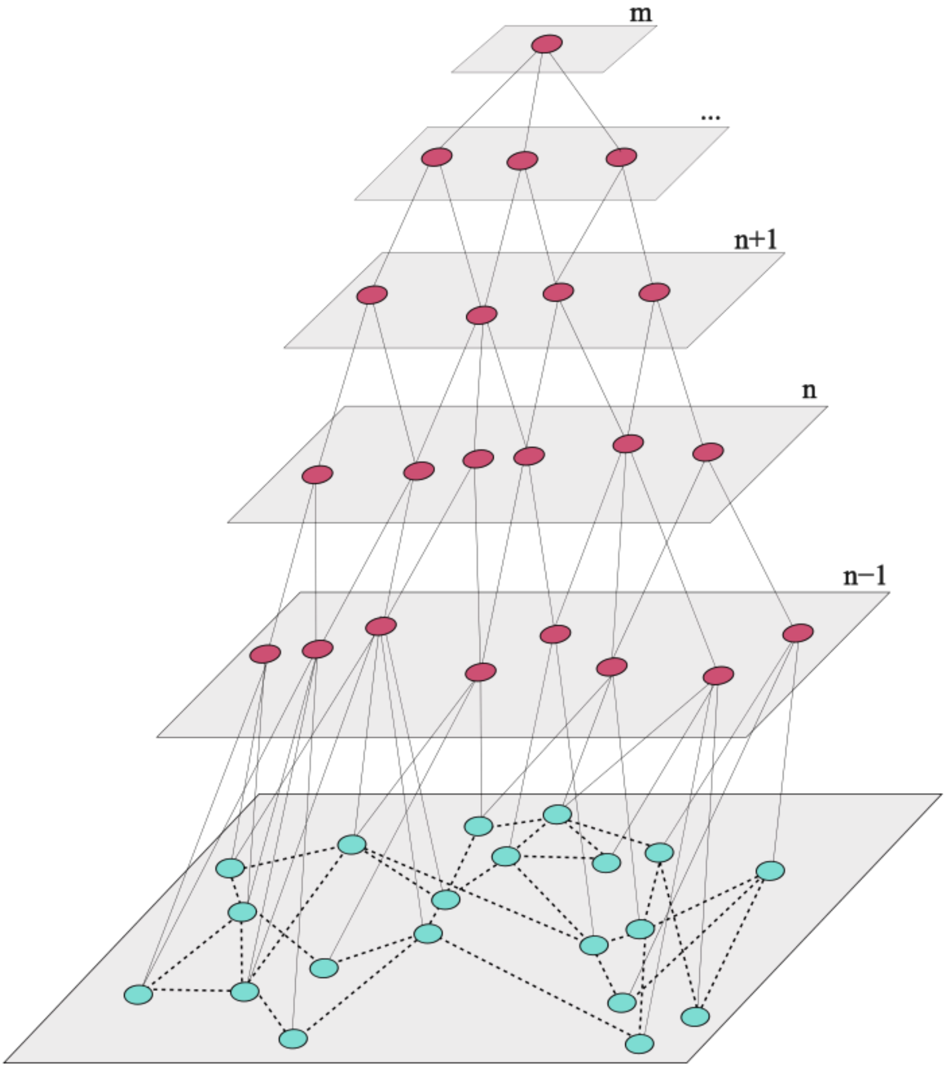

Figure 1: *The sensorimotor scheme transition -network (bottom) and the heterarchy of goals (red multilayered network on top), picturing global self-maintenance of sensorimotor organisation at the top (m level) and different*

A further degree of complexity arises when we introduce “disjunctional branches” and “conjunctional branches” (see Figure 2). On disjunctional branches to achieve a goal n, one *or* the other goal at level n-1 must be achieved. However, usually, the hierarchy also involves “conjunctional branches”: cases in which, to achieve a goal at level n, two distinct goals at level n-1 must be achieved. With disjunctional branches, we have alternative ways to achieve the goal, but with conjunctional branches, we need more than one lower-level goal to be achieved. Imagine you want to drink a glass of ginger ale (goal at level n). To do so, you need both a glass and ginger ale (conjunctional goals at level n-1). However, if you need to obtain a glass, you may have alternative means (disjunctional goals at level n-2), such as retrieving one from the kitchen cabinet or borrowing one from a friend.

The hierarchical view is important, among other things, to understand the relationship between means and goals and the consequences of not achieving a goal, which are, in turn, essential to understand error and to characterize genuine teleology. The rough idea is quite simple: if a means at level n-1 to achieve a goal at level n fails, we need to persist or deploy an alternative means. However, if there is no way to achieve the goal at level n (all means at level n-1 fail), then the goal at level n, which is a mean for goal n+1, also fails. We need an alternative goal at level n to achieve the goal at level n+1. If all goals at level n fail, goal n+1 also fails, and we must move on to higher level goals. Goal-directedness implies the capacity to navigate this hierarchy, i.e. a way of using alternative means to achieve different goals at different levels.

Here is an example (see description of nested goals in Figure 2). You really like fancy drinks, but you particularly enjoy and identify yourself with the habit of drinking ginger ale (GA), served specifically in your preferred highball glass (HG). As it happens, rarely a drink is just a drink. This drink satisfies more than the thirst you might have: it represents comfort, nostalgia, and your identity, making you feel at ease and socially connected during gatherings. So, you are at this party, and you first check the refrigerator (R) for ginger ale but find none. Unfortunately, neither is in the pantry (P), so you abandon the goal of finding one at home (H). You then consider an alternative: quickly going outside (O) to the nearby convenience store (S). At the store, you discover your preferred brand is unavailable. Frustrated, you try another alternative—visiting a café (C) close to the party that occasionally stocks ginger ale. Luckily, the café has it. Having secured the ginger ale, you now need to find your special vintage glass, and you know the only option is to find it in the kitchen (K). You first search in the host's kitchen cabinet (CK), but it’s not there. You then check by the sink (SI) and fortunately find your glass clean and ready to use. Success! You have both elements needed for your drink. Happily, you pour the ginger ale into your cherished highball glass, achieving your goal.

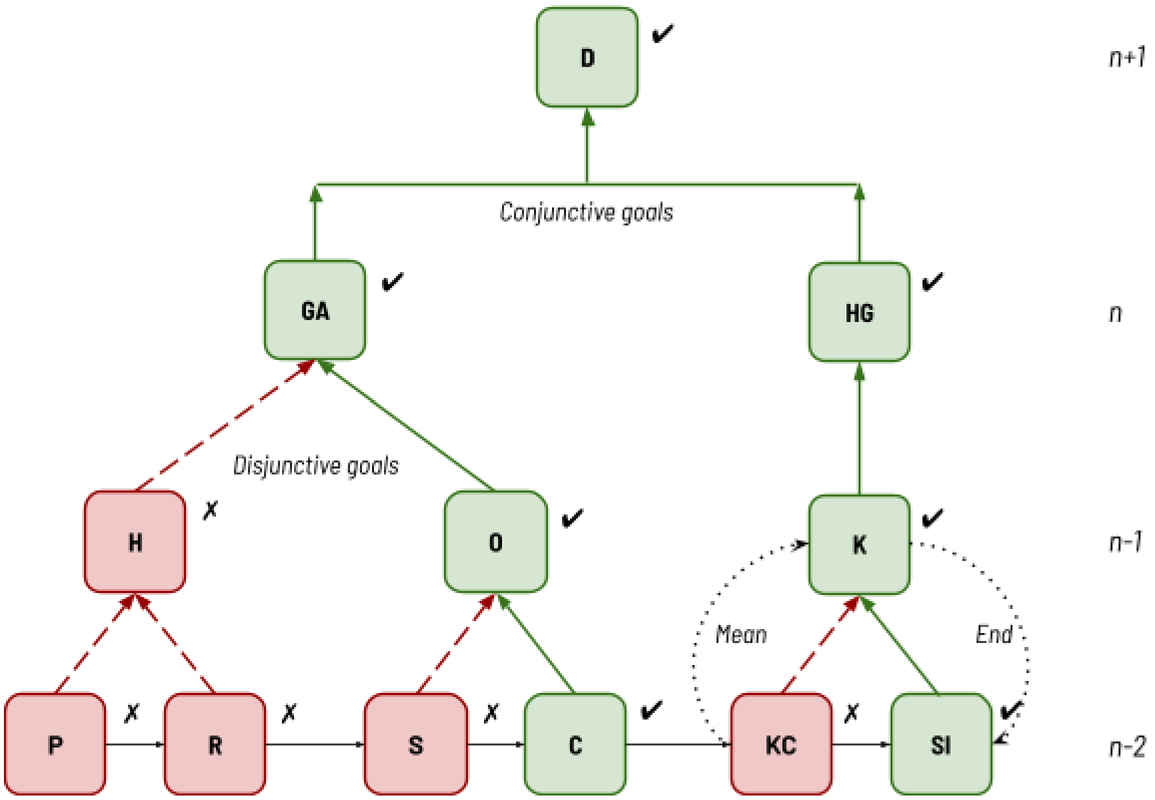

Figure 2: *Nested goals. Figure 2 depicts the core relationship between the levels of the heterarchy, showing the transition between branches where different behaviours are involved in achieving a ginger ale and the highball glass. Relationships between the nodes are described as a means-goal relationship: each node at level n is a means to achieve a goal at level n+1, and its goal is fulfilled by means at level n-1. See text for further description.*

3.3. Minimal requirements for sensorimotor teleology

We can now proceed to provide a set of minimal requirements to characterize teleological behaviour:

A behaviour is teleological only if an agent generates sensorimotor strategy X—a structure of sensorimotor schemes (x_1, …, x_i, …, x_n)—coordinated in relation to a particular node of a branch in the heterarchy of goals, so that the generative process *implies* its unfolding along the following scheme:

1. INITIATION: Behaviour is *initiated as goal-directed*.
2. MODULATORY EXECUTION: The behaviour is (potentially) modulated in relation to the goal during the task:
   a. COMPENSATION FOR PERTURBATION: The behaving system actively and systematically *compensates for perturbations* of its ongoing interaction, in relation to those goals.

b. ALTERNATIVE SENSORIMOTOR STRATEGY: The behaving system actively and systematically *deploys alternative sensorimotor schemes* y_i or strategies Y to satisfy the goal if obstacles are present.

3. TERMINATION: When the agent ceases to generate the behaviour, one of the following cases ensues:
   a. SUCCESS: The goal is satisfied. Further conjunctional goals might be necessary to achieve a higher level goal, or the system might move directly to other goals at different locations of the heterarchy.
   b. FAILURE: If the behaviour terminates, but the goals were not satisfied, then further behavioural consequences follow, typically:
      i. PERSISTENCE: A behaviour is generated again, and the following situations might occur (without chronological order):
         1. REPETITION: The same sensorimotor strategy *X* remains unchanged. Two modes are distinguished: A. Iterative, goal-directed repetition. B. Loopy or blind repetitions (precludes goal-directness).
         2. ADJUSTMENT: Subsequent instances of the sensorimotor strategy *X* are altered (X') with a more probable effect of increasing the chance of meeting the goal.
         3. SURROGATE: The agent generates a different sensorimotor strategy *Z* towards the same goal, coordinated with the consequences of having failed with the previous sensorimotor strategy *X*.
      ii. ABANDONMENT: The behaviour terminates and the system engages in another activity directed at a different goal at this level, but the same goal at higher levels (the system moves to another branch of the heterarchy).

All such possibilities, when considered together, are necessary to characterize a sensorimotor process as teleological. *It is the tension that coordinates all potential developments of the interaction process, from initiation to execution to termination, what constitutes the teleological nature of sensorimotor goal-directedness*. The whole arc (from initiation to termination) must be implied or dynamically presupposed, on each moment of the actual execution of the action for it to be teleological. This implication can take different forms according to different theories: behaviourists might want to call them dispositions, cognitivist might build this implication as representations of future or contra factual states, enactivists might treat them as *virtualities*. We shall now provide a more detailed account of each condition and how it is necessary for goal-directedness.

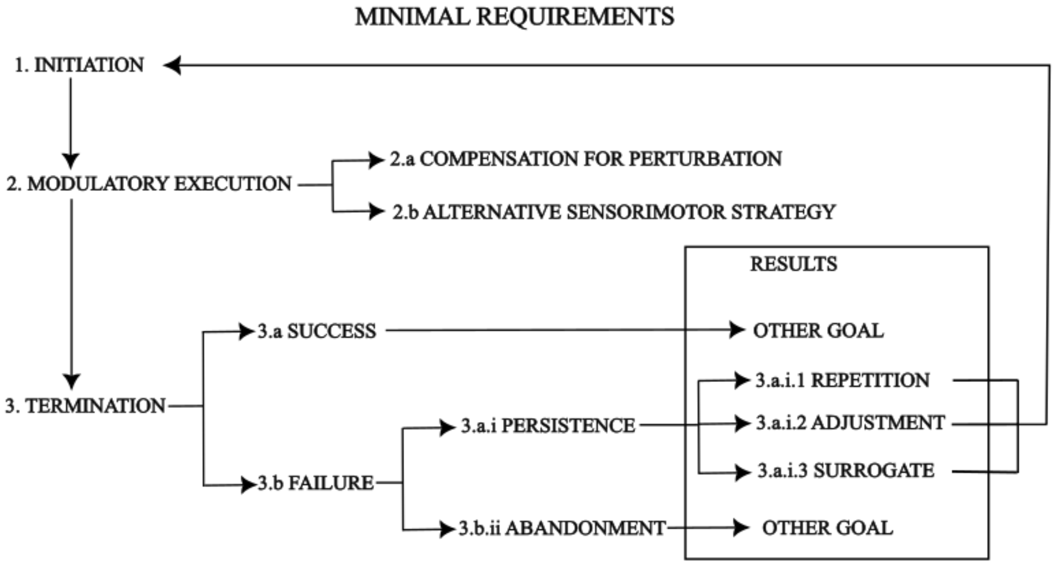

Figure 3: *Schematic representation of minimal requirements (see text for details)*

1. INITIATION: For a sustained organism-environment interaction process to be considered goal-directed, there needs to be an initiation that individualizes and structures the interaction as somehow “dependent” on the goal. This doesn’t mean necessarily that the only relevant causal factor be “internal” or “intrinsic” to the organism[12]. It is perfectly possible (and frequent) that some interactive processes get channelled by both internal and external factors, that might be completely under-determined by or neutral towards any goals (or many). But the process becomes an action as such, and goal-directed, when it starts being *shaped* by a goal condition. Initiation in this sense does not need to be an all or nothing trigger mediated or instantiated by a goal, but can perfectly be conceived as a gradual process, a process of initialization. Without it, the interaction process cannot be considered goal-directed. If I am walking on the street and I suddenly find a 50 Euros note on the floor, my walking on the street does not come to be retrospectively goal-directed towards unexpected encounter with the 50 EUR note, because it wasn’t initiated towards that goal (unlike, e.g., bending down to pick up the note). The nature of this goal-directedness is still to be fully unpacked, and it unfolds throughout the other requirements that are manifested as potentialities, counterfactuals or dispositions, that, unlike initiation, might not be actualized but remain constitutive of the goal-directedness, even at the initialization stage.

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[12] This is a classical, still pervasive, requirement of spontaneity or inner causation that many require for volitive or intentional agency (see Haggard, 2019).

2. MODULATORY EXECUTION: Classical requirements of teleology or goal-directedness are manifested during the execution of the action[13]. We call this the modulatory execution requirement, typically named *plasticity* and *persistence*[14]. There exists no real environment that doesn't continuously include variations of all kinds: from noise to blocking obstacles, passing through to various perturbations at different scales. As a result, there are few (if any) straight-forward movements that are executed as a one-shot blind process. All motor activity is continuously changing sensory activity in a manner that is often self-modulating and stabilizing; even the tiniest neuromuscular systems involve a complex ongoing coordination between afferent and efferent signals. Moreover, if the system-environment interaction process has potentially no modulatory capacity, it is but caused by fixed antecedent conditions, incapable of goal-directed flexible transformations. We distinguish two broad categories of such modulatory capacity. At the lowest level, we have COMPENSATORY modulation of environmental perturbations (e.g. the wind or small stones on the pavement requires that your muscles compensate these forces on the movement towards the goal). At the highest scale we have full obstacles whose overcoming requires the system to change to an ALTERNATIVE sensorimotor strategy to achieve the goal (e.g. the road to the grocery store is blocked, I need to take a different route). The deployment of modulatory compensations and alternatives in the face of variations in initial conditions (perturbations) or background conditions (obstacles) while maintaining the goal invariant is the hallmark of teleological explanations; unlike mechanistic explanations, where fixing the mechanism, variations on the initial or background conditions deliver varying results (Walsh, 2012). Thus, the (potential) deployment of compensatory behaviour in relation to the goal or the change of alternative strategies is essential to fully characterize the unfolding of the interaction as goal-directed.

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[13] Previous influential works that proposed a similar perspective are (Russell, 1945)—who directly influenced our proposal—and (McDougall, 1905)—whose work we came to know thanks to feedback from colleagues on the first manuscript; both being highly influential on latter classical formulations of the problem of teleology (Nagel, 1979).

[14] We have decided to change the classical labels. *Persistence* has generally been used to refer to the ability of a system to compensate for disturbances or changes (internal or external) that would otherwise deflect it from its goal. But we think the term *compensatory modulation* better captures this idea. We consider *persistence* to be most appropriate to name a different phenomenon that can both become a requirement for teleology or a sign of its absence: the repetitive exercise of a (goal directed) action. On the other hand, the term *plasticity* has been used to designate the ability of a system to reach the same goal-state from different initial positions or through different causal pathways. However, plasticity is a very general term that is currently used to name all sorts of behavioural change (e.g. learning) or neuronal change (e.g. neurogenesis or synaptic strengthening) that result from the exercise of behavioural activity. We have instead chosen the term *alternative sensorimotor strategies* to substitute *plasticity*.

3. TERMINATION conditions are perhaps the most critical, for they involve the achievement of the goal or the failure to do so, and thus manifest the purposefulness of the whole process. We must distinguish between successful and failure scenarios.

- 3.a. SUCCESS: If the action is completed and the goal conditions are satisfied, yet the agent persists, the goal-directedness of the whole action might be questionable (e.g. compulsive behaviour might require explanatory resources other than those of goal-directedness, or we might be simply facing a mechanical repetitive behaviour undifferentiable on its nature from that of set of gears). Thus, for an action to be teleological, there has to be some understanding of its successful completion. If a robot halts after completion of a task, it might simply have been instructed to follow a sequence of operations that lead to what an external observer considers a successful completion but remains indifferent to the robot. Intrinsic, teleological, goal-directedness emerges from an organized precarious network of sensorimotor schemes that constitute the identity of the agent. Thus, the completion of an act as a successful goal-attainment would necessarily transition (with due pace) to another one on the network to which it is, ultimately, normatively tied. Either the newly completed goal was part of an identifiable subset of the heterarchy (a means) of a higher level goal that requires more actions (I went to the grocery store to buy a ginger ale, so I return to the party to find my glass and complete my higher order goal)… or the transition occurs to another region of the heterarchy (I got my glass of ginger ale, I will now talk to a friend I haven't seen in a while).
- 3.b. FAILURE: Cases of failure (actual or potential) are even more informative of the teleological nature of the action. If potential failure is to have no consequences, the normative dimension of goal-directedness would be missing—this is typical of machines failing to comply with the goals that designers attributed to them. But not any kind of consequence of failure matters for the teleological characterization of a sensorimotor process. These are to be found among the broad categories of persistence upon failure or abandonment.
  - The PERSISTENCE of a system in the attainment of a particular goal upon failure can be seen both as a manifestation of teleology or the contrary, depending on the type of persistence and its relationship to the goal. If the system persists by deploying a SURROGATE strategy to attain the same goal we are, in fact, back to a variation of the MODULATORY-alternative requirement (or classical *plasticity* requirement). This time, the search and deployment of alternative or surrogate strategies to attain the same goal happens *after* failure in the completion of the act (not during it). The agent might however also persist through repetition with variations smaller than those of a surrogate strategy and that can be interpreted as ADJUSTMENT, that is improving over variations of the same strategy (e.g. repetitive throwing of a dart that we improve as we get closer to the target). Were

the system simply to persist by REPETITION *ad infinitum*, upon failure, the interaction process can hardly be characterized as goal-directed. It is instead blind to the consequences or results, as opposed to directed to a goal that is repeatedly unreached. But this repetition can take several forms, some of which, might, in turn, reveal teleology: A. *Iterative goal-directed repetition*: In some instances, the goal itself inherently requires more than one repetition of the behaviour for it to be achieved. Examples include knocking on a door multiple times to get someone's attention, applying multiple coats of paint to ensure full coverage, or repeatedly pulling the trigger of a malfunctioning gun to attempt firing. In these cases, the repeated actions are an essential component of goal achievement, and thus the behaviour remains teleological. B. *Loopy or blind repetitions*: Lastly, there are cases of loopy or blind repetitions, where the behaviour is repeated without any sensitivity to the goal. Examples of blind repetition include a malfunctioning washing machine that continuously cycles through the same program or a person compulsively checking a locked door over and over without any new information or changing conditions, a shocked soldier repeatedly pulling the trigger of an empty machine-gun. If failure was not to bring the system to a form of persistence that is goal-sensitive, the system was not acting in a goal-directed manner, unless it gives rise to abandonment[15].

- Finally, ABANDONMENT is the most delicate of the failing terminating conditions. If, upon termination of the interaction and failure, the system simply halts, it would imply no (public or externally observable) consequences. A system can be instructed to do so bearing no normative consequences, remaining indifferent to the failure of the termination, or having recorded the termination state “as failed” with no other consequence than the label of the final state. Abandonment is itself a special kind of termination that bears with it the “active” suspension of the goal, and leaves the trace of frustration, anger, regret, resentment or even relief, which in turn would modify the landscape of goals in some way. Abandonment of a goal at level n entails that a particular branch of the hierarchy must be abandoned and that the system must navigate through the hierarchy to fulfil other goals n+i. Abandonment, and due transition to another goal, should also reveal the teleological nature of the agent in terms of the consistency and coherency of the new goal in relation to the previous, or, ultimately, in relation to the whole network or identity of the agent.

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[15] There is a third kind of observable “repetition” that involves the execution of *the same sensorimotor scheme but directed to a different goal*: In some cases, the behaviour might look repetitive, but the underlying goal has changed, making it different from mere repetition. For instance, an agent repeatedly swiping a bank card that fails to register may initially aim to complete the transaction, but upon failure, the goal quickly shifts to verifying whether the machine or card is malfunctioning (this shift represents a change from a transactional goal to an epistemic one). In these scenarios, the repeated actions are goal-directed, but the nature of the goal itself changes with each repetition.

Because the goal-heterarchy is recursive and fractal, any of the requirements can be re-described at another level. A manoeuvre that looks like an *alternative execution* (2.b) from one vantage point can, seen up close, be a *persistent-surrogate* strategy under termination (3.b.i.1); likewise, a *persistent adjustment* (3.b.i.2) is simply a *compensation for perturbations* (2.a) viewed from further out, and *abandonment* is the switch that lets the system migrate to a new branch of the goal heterarchy. In short, norms nest inside norms. I may aim to catch a ball, which recruits arm-stretching, sprinting, and staying upright; success depends on how these micro-acts are continuously re-coordinated under the live presupposition that the catch will occur. What marks behaviour as teleological, then, is not the triumphant gulp of ginger ale (which might never come) but the self-organising network of dispositions that actively sustains that possibility open until switching to a new one.

With this layered picture in place, we can now turn to Section 3.4 and ask how error can be naturalized and teleology grounds its distinctive normative force.

3.4. Normativity and error revisited

It is the always lived and present, actual and potential, distance, lack, gap, err away from the target that makes a behaviour teleo-logical, that is, submitted to a logic or organisation of this distance. In a sense, then, it is error, that is continuously made and corrected for, or potentially doable, that makes a behaviour teleological. There has to be a meaningful (that is, perceivable and actionable, yet not necessarily perceived and acted upon) "distance" between the current state of the system and the goal conditions. That is, there has to be a sensitivity to the degree of approximation to the satisfaction of the goal conditions. And this sensitivity must be regulating behaviour from initiation to termination. So what is the normative character of this distance? How is its normative character justified, and where does the source of its normative force lie?

As explained above, biological normativity is anchored in the dynamic presupposition between different biological components causally involved in a given task. It is precisely the joint, causal action of these components that proves the end-state to be achieved. Behavioural norms are not defined by the evolutionary role of behaviour, but by the fact that there is a dynamic presupposition between different components that constitute a sensorimotor coordination. One of the alleged virtues of SETF is that it can explain how an individual organism can possess a trait (token) that does not fulfil its proper functions as defined by the evolved population (type) to which it belongs. This advantage is maintained in our proposal, but for different reasons: Our characterization of teleological behaviour does not imply that end-states are successfully achieved. A cognitive system can behave teleologically even if a malfunction prevents it from reaching a goal. Teleological behaviour is located in the unfolding of a sensorimotor coordination that goes through the steps described in our requirements, regardless of whether the end-state is reached or not.

At the most basic level, each habit is endowed with a basic sense of normativity as its own repetition is both the condition of its presence and of its future re-ocurrence. As we saw, this gives rise also to dynamic presuppositions between habits or sensorimotor schemas: my bending towards the fridge presupposes the movement of my leg to hold my weight, the muscular contraction of my shoulders moving my arm forward towards the handle presupposes my success on moving forward, the opening of my hand presupposes the grasping of the handle, etc. So, in a sense, the coordination and dynamic presupposition of different sensorimotor schemes between themselves and as means for a unified goal gives rise to an intrinsic form of normativity. Errors involve an incoordination between schemes, and consequently an incoordination between means and ends. From here we can scale up in the hierarchy to find vertical mismatches between the presuppositions and coordination of different conjunctive branches, or lower and higher means and ends coherency and consistencies, up to the whole identity/ies of the agent. The tension is nor released, the potential is not actualized, leaving traces behind that could ultimately jeopardize the identity of the agent. We are now in a position to apply this framework to a specific case study.

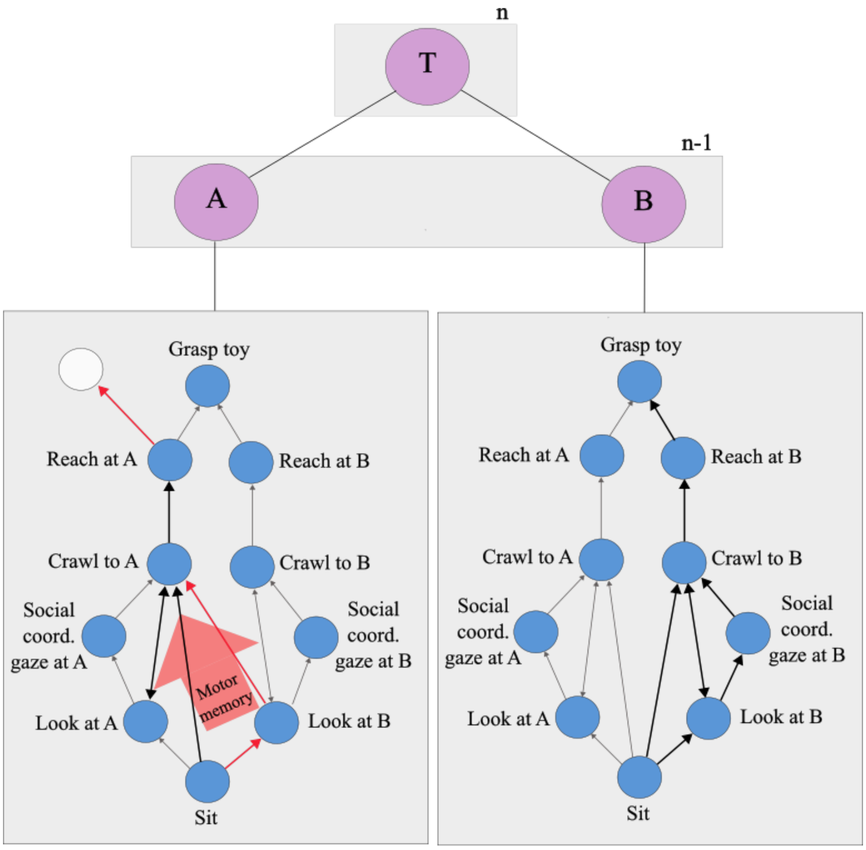
4. A case study: The A-not-B Error

Errors are certainly common, but systematic and relatively simple errors that can be reliably reproduced in experimental setups are quite rare—especially when they stem from basic human, or even animal, behaviour and lack complex linguistic or rational elements, such as the higher-order layers of thought built upon our sensorimotor experience of teleology or purpose. In this section, we present a case study to illustrate how to apply our view to a well-known phenomenon, Piaget's A-not-B error (Piaget, 1954). In particular, we will focus on three core elements of our view: i) how the minimal requirements are applicable to this case study, ii) how goal-directed behaviour in A-not-B errors can be subsumed into our hierarchically nested view of goals, and iii) how errors can be located on the dynamic presuppositions between the sensorimotor schemes and goals involved in the behaviour.

4.1. Piagetian A-not-B Error

There is a lot of theoretical and experimental literature on this case, with several experimentally analysed variants and a variety of interpretations, from Piaget's original representationalist view to Thelen and Smith's dynamic reading (foundational texts include: Clearfield et al., 2006; Munakata, 1998; Munakata et al., 1997; Schöner & Thelen, 2006;

Schutte & Spencer, 2002; L. B. Smith et al., 1999; Spencer et al., 2001; Thelen et al., 2001; Thelen & Smith, 1994). The classical A-not-B error is studied in infants aged 8 to 12 months. A toy is shown to the infant and then hidden in place A by an adult experimenter. The infant then successfully searches for the object at location A. This is repeated several times (at least 3 trials). The infant solves the task perfectly. On the fourth occasion, however, the toy is hidden in location B in the presence of the infant. After a delay of a few seconds (5-7 seconds), the infant *erroneously* reaches for the toy again at location A instead of going to B, where the toy is hidden. The error increases with the number of successive preparation trials where the object is hidden in location A before changing to B---the error increases also with the time between hiding and searching (but if the time is excessive, then the error does not occur), and this time must be higher if the child is older (8mo= 3s; 10mo=5s). The classic A-not-B bug disappears around 12 months old.



Sensorimotor Strategy I
A-not-B Error

Sensorimotor Strategy II
No error

Figure 4: Sensorimotor strategies and nested goals in A-not-B error: *(Left) Incoordination of sensorimotor patterns during the infant's search in box A (A), goal at level n-1, to find the toy (T), goal at level n. (Right) Error correction by coordination of sensorimotor patterns to find the toy (T) in box b (B). See text for more details.*

The same error has been shown to be non-age-specific under different experimental conditions (Schutte & Spencer, 2002; Spencer et al., 2001) and has also been found in other animals such as cats (Pongrácz & Onofer, 2020), dogs (Sümegi et al., 2014), horses, donkeys and mules (Osthaus et al., 2013). From this general perspective, the A-not-B error concerns the stabilization of certain sensorimotor patterns that cannot be appropriately modulated when certain variables in the environment are changed in a particular way (Clearfield et al., 2006; Schutte & Spencer, 2002).[16]

Figure 4 shows a simplified schematic of the central sensorimotor patterns in the A-not-B task and their relationship to the behavioural goals—see Thelen et al. (2001) for an overview. The A-not-B task begins with infants **sitting** and controlling their body position before searching. Experiments have shown that infants who are allowed to search standing rather than sitting during B trials significantly improve their performance (Lew et al., 2007; Smith et al., 1999). **Looking** and all associated movements are another sensorimotor pattern linked to search tasks. It is well known that infants do not make robust errors in A-not-B looking-tasks (Cuevas & Bell, 2010). In addition, many environmental cues have been shown to be relevant to the task, meaning that variations in these features influence infants' performance (Munakata, 1997). These include the characteristics of the toy used, the similarities between the hiding locations A and B---boxes, rags (Butterworth & Jarrett, 1982)---, other elements in the room, the characteristics of rags or boxes in relation to the background surface, and so on (Wellman et al., 1986). A key element of this task is motor coordination in **crawling** and **reaching** A or B. Repetition of A trials is central to the generation of perseverative errors by building motor memory for a hidden location (Diedrich et al., 2000). Infants tend to seek out the locations they have previously visited (Clearfield et al., 2006), so a higher number of A trials makes B errors more robust (Marcovitch & Zelazo, 1999). Furthermore, crawling requires complex self-orientation through space by controlling one's own movement in relation to specific environmental arrangements (Acredolo, 1985). For example, if children are moved to the other side of the table (now having location A and B inverted, right-left, in relation to the direction of the child) after the attempts in A (the infant going to the left), they are successful in the attempts in B because they continue to go to their left (Bremner, 1978). Another well-discussed variable is **social coordination**, a label we use to refer to other aspects involved in the task, such as the interaction between child and adult--- verbally, with

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[16] Although it lies beyond the scope of this article, perseverative errors underscore the importance of incorporating an additional scale of analysis in the study of normative behaviour: the developmental scale (Rama, 2025). While autonomous norms are typically defined in relation to current (synchronic) organizational conditions, a developmental perspective emphasizes the (diachronic) construction of autonomy over time. Normativity may differ when analysing processes at the psychological level (e.g., behaviour) from processes at the ontogenetic level (e.g., behavioural development). As Clearfield et al. (2006) argue, perseveration is an example of this distinction, as the occurrence of perseverative errors is, in fact, necessary and even beneficial for the emergence of flexible behaviour in the system.

the eyes or with gestures---, the way the experimenter performs the task, the presence or absence of the parent in the room, the place where the experiment is conducted---at home or in the laboratory (Acredolo, 1979; Dunn & Bremner, 2020; Smith et al., 1999; Topál et al., 2009).

As mentioned above, this is a simplified analysis of the elements involved. Further details will make this schema even more complex. Our goal is to provide evidence that in the A-not-B task multiple sensorimotor patterns are linked together to form complex sensorimotor schema and strategies to find the toy, as shown in Figure 4.

4.2. The minimal requirements in A-not-B Error

The minimal requirements presented in the previous section can be applied in this case, and most importantly, they allow us to explicitly justify why the infant's behaviour is teleological and why it made a mistake.

A behaviour of an infant participating in the "A-not-B error" setup is teleological only if s/he generates sensorimotor strategy X (identify hidden location of toy, crawl towards it, reach it, uncover toy, grasp it) coordinated in relation to a particular branch of the heterarchy of goals (reach location A, grasp the toy, play with it[17]) so that the generative process *implies* its unfolding along the following scheme:

1. INITIATION. The system initiates a behaviour according to the constraint. The complex sensorimotor schema in Figure 4 is involved in the search task. As noted, younger babies do not make the A-not-B error simply because they are unable to go to either box. So we can not say that any behaviour has been initiated, so there is no success or failure possible in this scenario.
2. MODULATORY EXECUTION
    a. COMPENSATION FOR PERTURBATION: The infant must coordinate the behaviour of different body positions while moving and maintaining their looking location, in which the infant also must couple its movement with the environment: the table, the distance of the box, the surface on which the infant is standing, and other environmental features that have been under study (Lew et al., 2007; Thelen et al., 2001). Furthermore, experiments in which A box is moved while the infant is crawling to A shows that s/he compensates for the change and re-directed towards the new location (Ashmead et al., 1993).
    b. ALTERNATIVE SENSORIMOTOR STRATEGIES: While we did not find a specific study on the A-not-B error analysing the presence of obstacles during search behaviour, the literature on motor modulation in infants confronted with obstacles

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[17] Other branches such as "please the adult" (parent, experimenter, etc.) might also be interfering or concomitantly generating teleological behaviour.

(steep slopes, cliffs, or stairs) shows that they are able to find alternative behaviours to reach a stable endpoint in space (Adolph & Franchak, 2017).

3. TERMINATION.
    a. SUCCESS. The error doesn't take place, and the infant finds the toy.
    b. FAILURE. The toy is not found where the infant was looking. Experiments show infant's violation of expectation by increasing social looking immediately after inaccurate search (Dunn & Bremner, 2020). Pupillometric analysis also evidences violation of expectation in object permanence tasks (Mayer & Liszkowski, 2025).
        1) PERSISTENCE: The infant still persists on finding the toy. The experiment is re-initiated.
            A. REPETITION. The error persists over several attempts, usually between 5 and 7 trials, which is referred to as the error run (Butterworth, 1977). The error persists since motor memory is usually coordinated with the previous A-trials, so that the motor memory overrides the short-term memory.
            B. ADJUSTMENT. The error is corrected after some trials and the infant correctly searches in B.
            C. SURROGATE: Although, to our knowledge and surprise, little academic record exists of what happens right after the failure (without re-initiating the trial), experimental psychologists report (personal communication) that, in some occasions, infants search for the toy on location B after failure (directly from location A).
        2) ABANDONMENT: Since the experiment is determined according to experimenters' goals, abandonment is not a well-studied phenomenon. However, most experimental analyses refer to cases in which infants abandon the task, for instance, due to infant's fuzziness. Other experimental cases are eliminated because the infant interacts with its parents during the tasks, becomes frustrated and gives up the search, or because infants in A-trials do not show robust interest in the toy.

Our view follows the dynamicist interpretation of Thelen & Smith (1994), in which they propose that "the processes that make a goal-directed reach are the processes that make the A-not-B error." (Smith et al., 1999). Behaviour arises from the dynamic presupposition of different sensorimotor patterns coordinated toward the achievement of a specific goal. This is how we were able to localise the error: as a *sensorimotor incoordination* between the different elements involved in the emergence of behaviour (see Figure 4, left side). The system is not able to properly modulate the different sensorimotor components involved in the behaviour and causing the error. There is a tension between two sensorimotor strategies---between two fields with different attractors (A and B locations). More specifically, the field towards the A location, which is generated by the motor memory generated on previous A trials, is in tension with the field towards the B location, which is formed by the short-term memory for the toy hidden at the B location. As several analyses of the A-not-B error show, the tension between fields with different attractors leads to incoordination between sensorimotor patterns: *crawling to A and looking to B* (Clearfield et al., 2006; Diamond, 1985; Spencer et al., 2001), *social coordination to A and looking to B* (Dunn & Bremner, 2020; Smith et al., 1999; Topál et al., 2009), *sit and crawling to A* (Lew et al., 2007; Smith et al., 1999). Here we see different types and strengths of habit or sensorimotor inertia and their complex interplay. The characteristic of a raw habit as a sensorimotor scheme is that its goal is to repeat or sustain itself, this enters in contradiction with the more complex and articulate goal of reaching the toy. While there are further incoordinations and the granularity of our schemas must be deeper, it is sufficient for us to illustrate the core idea of sensorimotor incoordination both at the level of concurrently and sequentially enacted sensorimotor schemes (looking vs. directional crawling) and at the level of conflicting goals (habit vs toy reaching, toy reaching vs. adult satisfaction).

5. Discussion, Conclusions, and Prospects

5.1. Goal-Directedness, teleology, purposefulness, and intentional agency

It is crucial to distinguish the phenomena our sensorimotor teleology aims to capture from related concepts. An artifact's 'purpose' or 'goal' is typically assigned externally by its designer or user. Such systems may be said to be goal-directed, following pathways towards externally defined end-states, but they are not genuinely *teleological* or *purposeful* in the sense grounded in the precarious self-maintenance of an autonomous agent. The intrinsic normativity and teleology displayed by autonomous sensorimotor agents[18], that stems from the dynamic presuppositions within the sensorimotor organization, manifests as a complex set of tensions established by the goal heterarchy. This heterarchy creates a high-dimensional *normative field* (Barandiaran, 2025) that structures the agent's sensorimotor space. This field, extending from the most general goal of self-maintenance down to the most specific commitments regarding immediate movement, guides behaviour as an evolving landscape of possibilities and constraints that the agent navigates, endowing it with purpose.

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[18] How biological norms are transferred to the sensorimotor organization (and transformed by it) is out of the scope of this paper. But suffices to note that the sensorimotor schemes are supported by environmental, neural and bodily processes, some of these bodily processes can converge into a form of internal environment where physiological-neural coupling can have a strong influence on the shaping of sensorimotor landscapes and tensions.

While teleological behaviour involves navigating the existing normative field according to the system's goals, *intentional agency* emerges when the agent gains the capacity to actively modulate this normative landscape itself. An intentional agent does not merely navigate a normative field of tensions defined by current goals; it actively shapes and re-organizes the field by fixing commitments to specific goals, selecting different branches of the hierarchy, prioritizing certain constraints and organizing strategies. Thus, *not all teleological behaviour is intentional*. An agent's behaviour can satisfy the minimal requirements for teleology without necessarily exhibiting the meta-level capacity to reshape the underlying normative field that defines those goals. It is reasonable to assume, for instance, that infants committing the A-not-B error exhibit teleological behaviour directed towards retrieving the toy. However, their perseverative error and the nature of incoordinations suggests an inability, *in that specific context*, to adequately modulate and navigate the normative landscape, indicating a limitation in their full intentional control over that action sequence, despite the underlying teleological organization.

5.2. Beyond hierarchy and finality

Furthermore, it must be acknowledged that our focus on a hierarchical nesting of goals, while useful for exposition, represents a simplification. Natural behaviour rarely involves optimizing for a single, isolated goal pursued down a distinct branch of a hierarchy. As the example of desiring a specific drink like ginger ale in a particular highball glass illustrates, real-world actions are typically exercises in *multiple constraint satisfaction*. Behaviour unfolds within a complex web where physiological needs (thirst), learned preferences (brand), social conventions (hospitality, glass type), personal history (nostalgia), and situated opportunities that dynamically interact. The normative field is thus shaped not just by a primary goal, but by the interplay of numerous, often partially conflicting, constraints and goals operating concurrently across different levels and domains of the agent's life. Developing a fuller account of how agents navigate this richer landscape of multiple, interacting constraints remains a significant prospect for future work.

Empirical studies of intentional action (Van Orden & and Holden, 2002) and models of self-organized critically in sensorimotor systems (Aguilera et al., 2015) have shown that 1/f noise across behavioural and neurodynamic timescales is a signature of deeply embedded, fractally organized coordination. These findings support the thesis that the presence of pink noise serves as an indicator of integrated, norm-governed agency—an embodied enactment of sensorimotor teleology where nested goal structures and their dynamic presuppositions sustain coherent, adaptive behaviour. Genuinely teleological behaviour—as characterized by the heterarchical and multiscale organization of sensorimotor goals—should manifest as interaction-dominant dynamics, expressed as 1/f (pink) noise.

Some avenues are open for further explorations. A relevant aspect of normative behaviour concerns cases in which behaviour is not directed toward an end. For example, proscriptive behaviour—such as "do not cross this line"—does not appear to be directed towards an end state, but away from it. However, it is possible to make a mistake and cross the line. It is possible to advance how our framework can accommodate cases of normative behaviour other than prescriptive or finalistic ones. If we recover the generic notion of constraint and the conception of teleological behaviour as constituted of tensions, then, as we advance earlier, proscriptive constraints can be understood as repellors in a state space. Other forms of sensorimotor normativity might also be accommodated on our framework: like effectiveness (translated into the optimal shape of transient paths towards the goal), gracility (as smoothness of the trajectory and the compensations for perturbations), style consistency (as characteristic signatures of navigating the sensorimotor space towards the goal), technical accuracy (as context and goal sensitive compliance with a given target or model arrangement of sensorimotor schemes), or ritual fidelity (matching a stereotypically structured sensorimotor scheme sequence).

5.3. The organismic path to teleosemantics

Teleosemantics was celebrated as an outstanding naturalistic theory of mind. However, the commitment to an evolutionary perspective on natural teleofunctions has called into question the viability of this alternative. By maintaining a teleosemantic strategy--- i.e. resorting to the biological foundations of teleology, normativity, and functions---, we have brought into play an alternative biological framework that stands in contrast to the evolutionary neo-Darwinian approach. This article is an attempt to use the rich conceptual and scientific toolkit of autonomous systems theory to address a classic philosophical problem: How can systems behave purposefully, make mistakes, fix them, find alternative ways to achieve a goal, and maintain their behavioural or psychological identity through a complex and convoluted flow of behaviour.

In this path, we identify four contributions that deserve to be highlighted: 1. That *goals are better understood as specific types of second order constraints* that can be captured through the notion of transient attractors in a sensorimotor landscape; 2. That *goals appear nested* in a meshed hierarchy whose branches are constitutive of their being the basis of teleological behaviour, 3. That *teleological behaviour is constituted by the tension that coordinates all potential developments* of a sensorimotor interaction process in relation to node and branch of the goal hierarchy, from initiation to execution to termination (and the identification of such necessary requirements); and 4. That *behavioural error can be conceptualized as incoordination* between sensorimotor patterns, understood as the incapacity to satisfy dynamic presuppositions required for the attainment of goals and their ultimate contribution to the self-maintenance of sensorimotor organization.

We believe that these points have not been systematically addressed by the philosophical tradition in which this article is rooted, although we recognize earlier efforts along this path. In particular, the characterization of behavioural teleology is a central goal of the cybernetic tradition that has flooded the autonomous view of life and mind. What is our proposal specifically about?

- First, the characterization of teleological behaviour has traditionally relied heavily on persistence and plasticity, leading to several problematic cases of behavioural error. However, our minimal requirements go beyond persistence and plasticity and offer a finer-grained analysis that considers not only behavioural errors but, more importantly, their consequences.
- Second, the organismic roots of our approach are essential to understanding the naturalistic basis of teleological behaviour. Goal-directed behaviour is an emergent property/state of an environmentally embedded and dynamic sensorimotor strategy. This differs from earlier cybernetic explanations, which have a strong reductive tendency. The advances of autonomous systems theory have called for a different ontology in which goals are real things in the world.
- Third, a central element in our proposal is the *modal profile* of teleological behaviour: goal-directed behavioural explanations are robust across different counterfactual scenarios than purely mechanistic (non-teleological) explanations. The modal profile of teleological explanations has also been noted by the cybernetic tradition. However, our view of nested goals anchors and exploits the modal profile of teleological behaviour by highlighting the consequences of behavioural teleology: whether failure or success, the action of the system will produce transformational states across the nested heterarchy.

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