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The motionable mind: How physics (dynamics) and life (movement) go(t) together—On boundary conditions and order parameter fluctuations in Coordination Dynamics

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Abstract This tribute to Hermann Haken, the great theoretical physicist, explores the idea—based on a reconsideration of the experiments that led to the HKB model—that intentions (an emergent 'mental force') are hidden~exposed in order parameter fluctuations that arise due to special boundary conditions or rate-independent constraints on the basic coordination dynamics of human brain and behavior.

1 Introduction

Could he whose rules the rapid comet bind
Describe or fix one movement of his mind (Alexander Pope, 1773–1774).
Chance and Necessity: Reality needs both (H. Haken, 1977 [20]).

For many years, Hermann Haken always wrote to me in his own hand (in later times delivered as a pdf!). I provide a single example,[1] his response to an article I wrote for a special book to celebrate his 90th birthday [39, 56].[2] Haken's letter (Fig. 1) conveys a sense of our longstanding friendship and collaboration. Often, when we were together "enjoying life" as he liked to say, he would look me in the eye and out of the blue, announce "You know, Scott, true scientific collaborations are made in Heaven". Ours was like that... Enough said.

So, what was it all about? In the beginning, as someone who was trying to understand the seemingly mundane problem of how the brain coordinates and controls limb movements and speech, Synergetics was a godsend: an entirely new set of concepts, methods and mathematical tools to potentially understand how patterns of coordination are formed in complex systems, how they persist and how they change. The challenge was how to realize these ideas in an experiment [33, 34]. For Hermann, the latter provided a much-needed concrete example—outside the world of laser physics—where he could ingeniously apply his theory of how spatial, temporal and functional structures arise due to self-organizing processes in open, nonequilibrium systems [20]. The outcome of this marriage?

The term "motionable mind" is taken from a poem by Gerard Manley Hopkins (1844–1889) titled "The Wreck of the Deutschland".

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[1] And even more recently (May 26, 2024) in response to a recent *Scientific American* piece: https://www.scientificamerican.com/article/how-do-babies-realize-they-can-influence-the-world/.Hermann wrote, this time by email 😊, "Many thanks for your pioneering paper. I still remember your first ideas some years ago"—as expressed in a special issue of *Journal of Nonlinear Phenomena in Complex Systems* devoted to Hermann Haken on his 75th birthday [36]. In between was still another conference held in his honor in Hannover, this time on "Complexity and Synergetics" (Muller, Plath, Radons and Fuchs 2018 [59; see [13, 18]).

[2] An early conference on Complex Systems celebrated Haken's 60th birthday [50].

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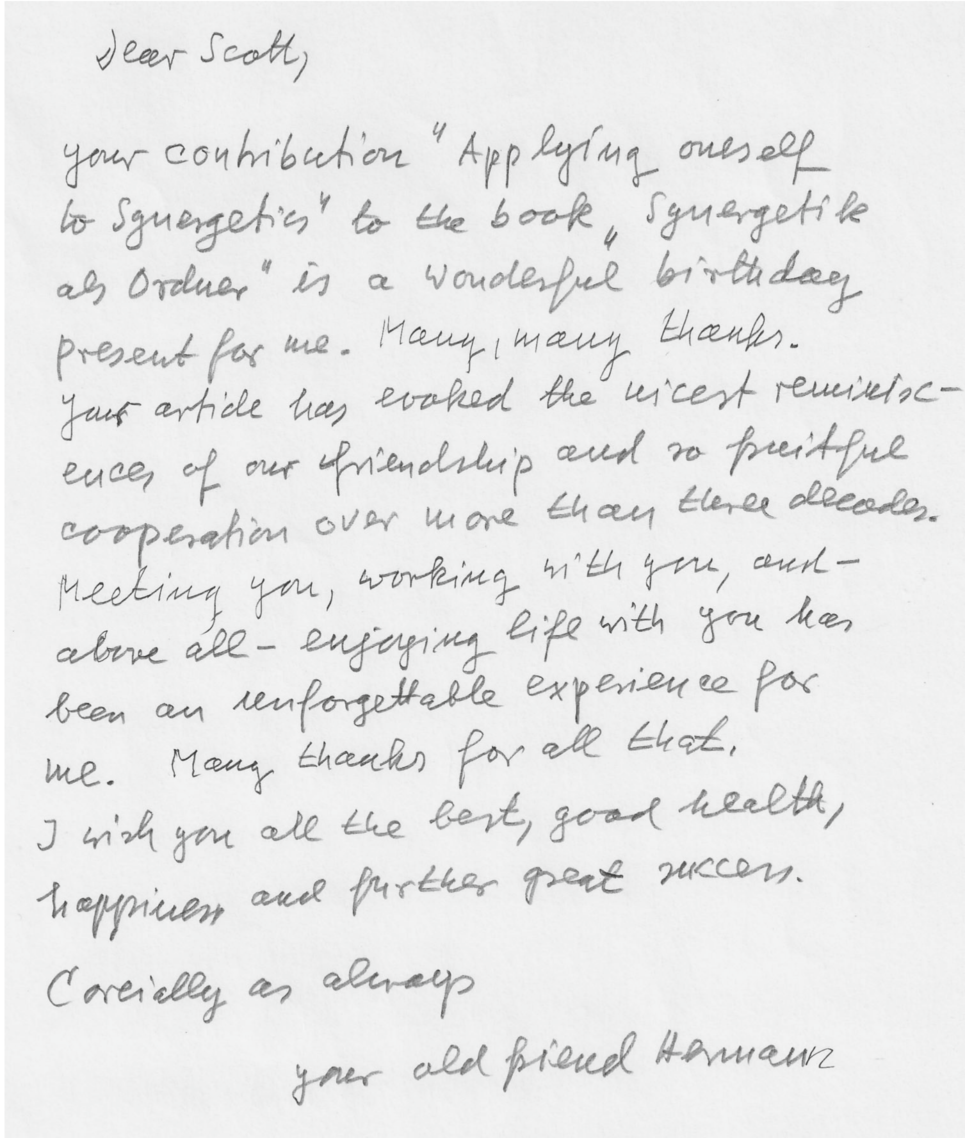
Dear Scott,

your contribution "Applying oneself to Synergetics" to the book "Synergetik als Ordner" is a wonderful birthday present for me. Many, many thanks. Your article has evoked the nicest reminiscences of our friendship and so fruitful cooperation over more than three decades. Meeting you, working with you, and – above all – enjoying life with you has been an unforgettable experience for me. Many thanks for all that. I wish you all the best, good health, happiness and further great success.

Cordially as always

your old friend Hermann

Fig. 1 Hermann Haken's letter to the author in response to Kelso [39]

The Haken–Kelso–Bunz model ([24], see [40–42] for invited retrospective and generalizations, respectively) and, along the way, the birth of Coordination Dynamics, a new science of coordination grounded in Haken's Synergetics.

Let me be explicit about what was at stake here, scientifically speaking, because it is easy to take it for granted. Say I ask you to make a fist. Babies do it already. To make a fist requires the coordination of many unique muscles, bones, fingers, sensors in joints and muscles, sensory and motor neurons, and their excitatory and inhibitory connections in the spinal cord, as well as multiple cortical and subcortical structures in the human brain—a huge number of degrees of freedom [17]. And even that does not take into account context or how my instruction to make a fist is perceived and understood! As the great linguist, Noam Chomsky recently remarked, no one understands how you move your finger, never mind how you decide to. *"It's as if we're coming to understand the puppet and the strings, but we know nothing about the puppeteer. That remains as much a mystery as it has been since classical Greece"* ([9], p.60). Fifty years ago, I would have said the same [32, 53]. Until Synergetics came along.

Even as far back as his famous book *Synergetics, An Introduction: Nonequilibrium Phase Transitions and Self-Organization in Physics, Chemistry and Biology,* Haken [20] proposed the idea that ultimately our thoughts are order parameters. Some years later, in his *Principles of Brain Functioning* [22], he again addresses order parameters and the mind–body problem in the context of our experiments on phase transitions in the human brain [19, 30, 55]. How can an immaterial quantity, such as an order parameter—in the latter case a relative phase—steer the behavior of a material system such as neurons and muscles? Mathematically speaking, as Haken pointed out, there is no problem. Both the relative phase and the individual components can be described by physical quantities and their equations of motion. According to the slaving principle (an unfortunate name perhaps), the individual parts with their variables q give rise to order parameters, ξ which in turn govern the behavior of the parts:

$$q = f(\xi).$$

Notice q represents the variables of the material constituents (neurons, muscles, joints, limbs, sensors, people, etc.), whereas ξ is an immaterial quantity (the mind?). One interpretation, then, is that q gives rise to ξ, that is, matter gives rise to mind. On the other hand, by analogy to Newton's law, $ma = F$, where the force, F is the cause of the particle's acceleration, we could equally well say mind determines the behavior of matter. Mind and matter thus appear to be two sides of the same coin—one might even say they are *complementary* [43, 44]. Or more specifically, perhaps, two modes of description, symbolic and dynamic, of a complex system [63], see papers in [64, 66]. Here, in this tribute to Hermann Haken, I shall try to put some new clothes on the issue, by taking a closer look at how mind and movement are related in real experiments (see also contributions in [2]).

I return ('where else'?) to the origins of our collaboration, the so-called Haken–Kelso–Bunz [24] or HKB model of movement and in particular an analysis of the experiments that led to that model.[3] Some of the conceptual and methodological consequences of the HKB model for the brain, behavioral, cognitive, social and developmental sciences have been spelled out in a recent retrospective ([40] see also [49]). In particular, the case was made that HKB and its many extensions in research laboratories round the world constituted the foundation of a mechanistic science of coordination called Coordination Dynamics which extends across a range of disciplines and phenomena one could never have imagined, including, e.g., economics [31, 71], politics and the city [65], ecology [1], philosophy [6, 73] and the law [5]. The inspiration for all these developments and more, of course, originates from Haken's *Synergetics*.

Here, I attempt to go a step further, namely to make a direct connection between the theoretical–mathematical HKB model and certain underpinnings of the model that have to do with special *boundary conditions* or *rate-independent constraints*. The outcome of the present analysis suggests that the HKB model (and its various extensions that include, e.g., symmetry breaking and multiple components) may not only be a lawful description of biological coordination but also provide insights into the linkage between mind, matter and movement. The perspective and interpretation offered here involves an intimate connection between *fluctuations* (typically viewed as physical causes) and *intentionality* (typically viewed as mental causes). I believe Hermann would have appreciated this line of thought because it favors physical–mathematical theory and experiment, an aspect of science he always stressed.

2 Matters of mind

As many great scientists and philosophers of the past have noted, how you get end-directedness into physics is a big problem. Newton himself, in a letter to Oldenberg [60] said "The power of life and will by which animals move their bodies with great and lasting force... demonstrate that there has to be other (undiscovered) laws of motion." Or Niels Bohr [4]: "A description of the internal function of an organism and its reaction to external stimuli requires the word *purposeful* (italics his) which is *foreign* (italics mine) to physics and chemistry…" Or Schrödinger [72] in his famous book *What is life?* asks: "If my body functions as a pure mechanism according to the Laws of Nature, what is this 'I'?" Teleonomy, as a distinctive aspect of living things, continues to be warmly debated and elaborated in theoretical and evolutionary biology (e.g., [10]). It is far from being a dead issue.

How might we reconcile intentionality and physics?[4] A first step, obviously recognized by Hermann Haken lies in understanding how intentionality, as a property of mind, may be viewed in light of the synergetic concepts and phenomena of emergent, self-organized pattern formation in open, nonequilibrium systems ([35], Ch.5), [77, 78]. A key part of the answer lies in appreciating the *functionality* of living things (see also [67]). The fact that the same empirically verified nonlinear dynamical laws have been demonstrated to underlie the functional coordination of living things, irrespective of their material realizations, is indisputable and will not be reviewed further here [46, 47], for recent reviews see [40–42]. This of course was a central theme, indeed a likely motive for Synergetics in the first place ([20], see [57] for cogent comparison of Haken's *Synergetics* with related efforts such as Thom's *Catastrophe Theory* and Prigogine's *Dissipative Structures*).

[3] Of course, our collaboration was not limited to this early work, and included, e.g., the synergetic computer and dynamic pattern recognition [25], analysis and modeling of pattern dynamics and phase transitions in the human brain (e.g., [19, 30], see [22, 35] for reviews). Along with notable biologists, we also addressed Schrödinger's question "What is life?" at the 50th anniversary of his book by the same name [45].

[4] The word intention here is used to capture a, perhaps *the* distinctive feature of mind, used to generally characterize mental acts called wishes, desires, purposes, goal seeking, etc. (see [37]). The term "mental states" is often used, though the state variables are seldom, if ever, defined. Instead, recourse is often made to "underlying" neural terminology.

An important step to bring Synergetics into the realm of cognitive activity (e.g., studies of pattern recognition by humans and machines) was taken quite early (as always) by Hermann Haken in his book *Information and Self-Organization* [21]. Since the concept of entropy is defined only for equilibrium or close-to equilibrium systems Haken turned to the concept of *information* to handle self-organizing systems referring to this step as the "2nd Foundation of Synergetics". More recently, along with Juval Portugali, he drew explicit connections between Synergetics (as a theory of self-organization) and the information-theoretic ideas due to Ed Jaynes (Maximum Information Entropy Formalism) and Karl Friston (Free Energy Principle; see [23]). Putting these matters aside for the moment here I want to address the issue of reconciling (or not) the physical and the mental by re-examining what is going on in human experiments and how they have been interpreted. What turns out to be central, and it may be no surprise to physicists, is the significance of fluctuations, their nature and what the fluctuations are of. What might prove surprising, on the other hand, is the putative connection of fluctuations to intentionality and cognate terms such as purpose and agency.

3 Brief background: "Experimental synergetics"

The self-organizing dynamics of pattern formation in open, nonequilibrium systems *aka Synergetics* infiltrated psychology and physiology with the discovery of phase transitions in the voluntary bimanual movements of human beings [33, 34]. The significance of that work was not about finger wagging or wiggling per se, as the paradigm is commonly referred to, but rather in its introduction of novel dynamical concepts, the means to identify them, and a specific way to visualize them, viz., a theoretical model (called the HKB model) that captured all the experimental observations and derived the underlying dynamics. As already mentioned, this now "classical" example encouraged a spread to many other fields. It may be worth looking into why.

Consider the four empirical facts of the original experiments: (1) the existence of two basic modes of coordination, which one is observed is established by initial conditions; (2) as the parameter of movement frequency is increased (either voluntarily or by means of an auditory metronome or visual pulsing stimulus), one pattern (anti-phase) switches to another (in-phase) but (3) not *vice-versa*; (4) after the switch occurred, when frequency was decreased, the current pattern did not switch back. These four facts (novel at the time, but reproduced many times since in many different contexts) were explained by a dynamical model that contained several key new concepts: (1) the concept of order parameter; (2) the concept of control parameter(s); (3) the concept of bi- or multi-stability; (4) the concept of attractor and attractor landscape; (5) the concepts of fluctuations and instability; (6) the concepts of bifurcation and phase transition; (7) the concept of hysteresis. These essentially nonlinear dynamical concepts were realized in a mathematical model that covered all the empirical observations and could be derived from the activity of the individual components and their interaction. In this way, the physics of self-organizing dynamical systems entered psychology (and the cognitive and brain sciences), not as an armchair, a posteriori description, but as a quantitative model of observed phenomena at the level of human behavior—in a directly analogous fashion to phenomenological approaches at other levels.[5]

In addition to providing a compact description of the original experiments, for reasons that will become obvious, we draw attention to a few key additional features:

(i) The HKB model included both deterministic and stochastic (noise) aspects, the full stochastic version taking the form of a Fokker–Planck equation in which the (Gaussian, delta correlated) noise term is a constant (see below).
(ii) Phase transitions are hypothesized to occur due to the softening of the HKB potential under the influence of a control parameter (e.g., movement rate/frequency in experiments).
(iii) As a result of (ii), the same (fixed) level of "noise" has a corresponding greater effect as the system approaches a critical point or transition.
(iv) The result of (ii) and (iii) is an increase in observed fluctuations as the system approaches a critical point or instability, a prediction of the HKB model known as *critical fluctuations*.
(v) A corresponding effect is that the experimental system takes longer to stabilize when perturbed, e.g., by an external force as it approaches an instability, a prediction of the HKB model known as *critical slowing down*.

[5] Though often ignored, the original Hodgkin–Huxley [28] model of the flow of electric current through the cell membrane of a single giant squid axon was explicitly phenomenological, i.e., equations for experimental observables only: "Our equations are [nothing] more than an empirical description of the time-course of the changes in permeability to sodium and potassium. An equally satisfactory description of the voltage clamp data could no doubt be achieved with equations of very different form" (p.561).

(vi) Various related predicted effects of the basic stochastic HKB model (later exposed fully in [70],see also [54] include the distribution of switching times and the mean first passage time all of which were calculated from the empirical data and shown to match the model.

(vii) The fact that the system never returns to the originally prepared pattern is due to hysteresis, a kind of primitive memory well known to physicists and engineers.

(viii) A great deal of HKB and consequent work focused on the identification and analysis of the individual components (nonlinear oscillators) and their (nonlinear) coupling.

The principal focus here is the collective, order parameter level, and specifically on order parameter fluctuations. As Hermann Haken said: *In the transitions generally studied in Synergetics, fluctuating forces play an important role. Extrapolating to the present case, a transition can be initiated only if fluctuating forces are present* ([24], p.353). The inclusion of a noise term is typically considered to represent additive random fluctuations due to external factors [29]. This is not necessarily the case in biology, or at least in the case of (the essentially nonlinear) HKB model of coordination dynamics (as I will suggest here) where fluctuations may arise due to *intrinsic* sources of variability. In this case, I submit, fluctuations can alter the system's stability—advance or delay instability—by virtue of rather special *boundary conditions*. What are these?

4 On boundary conditions and fluctuations

All the observed and predicted phenomena modeled by HKB occur in experiments in which human subjects are given the instruction "Do not intervene". That is, human subjects are instructed to move their fingers in an alternating fashion at a certain rate specified by a metronome—keeping the beat with it—and should they feel the pattern "wanting" (as it were) or "beginning to change", *let it happen*. Do not try to prevent it—hence, "do not intervene"—allow your fingers to adopt whatever pattern is comfortable under the current conditions. Any changes in coordination that occur due to the changing speed of the metronome are thus deemed to be *spontaneous*. This is quite amazing, is it not: the physically based modeling of movement coordination handles fluctuations beautifully using the Fokker–Planck formalism, yet the causes of the underlying fluctuations appear to have a "mental" and seemingly deterministic source, namely to "let go". To be quite clear, "letting go" or "do not intervene" is an intentional act all on its own. Spontaneous phase transitions,[6] accompanied by signatures of instability such as critical fluctuations [51], are a direct reflection of that.

It seems extremely likely that were the subject instructed "to hold on" to the current pattern as long as possible, that the structure of the fluctuations would change. The intention not to intervene has the dual counterpart of *intentional stabilization*. Studies show that human participants can stabilize a given coordination pattern or state under conditions (control parameter values) in which it would otherwise become unstable and switch. In other words, it seems that human beings can intentionally reduce the level of fluctuations. Such differential effects of stabilizing and destabilizing coordination states have also been observed in the human brain (e.g., [12]). In other words, to the extent that the boundary conditions qua instructions to participants in the experiment are obeyed—whether to let go or hold on—the magnitude and structure of the order parameter fluctuations are indicative of the human subject's intentions. One might even propose that *intentionality is hidden in the fluctuations*.

It could be argued that the subject's intentions, whether to let go or hold on, are quite deterministic and hence can be incorporated into the HKB model by adding an additional parameter corresponding to "intentional forcing" [52, 69]. The role of the latter is to sharpen or deepen the HKB potential for the same values of the control parameter. Thus, the effect of a given level of fluctuations is lessened due to the increased curvature of the potential, hence reducing instability and delaying the transition. However, logically speaking, Occam's razor requires us not to add parameters to a theoretical model merely to accommodate additional effects. (Coordination Dynamics is a bit different than AI in this respect). The stochastic HKB model only has to allow the magnitude of stochastic fluctuations (corresponding to the strength of the subject's intentions) to depend on the boundary conditions in the experiment—without necessarily requiring the addition of any new parameters.

What I am suggesting is that the connection between so-called "deterministic fluctuations" (unrelated to chaos theory and a placemarker for now) and boundary conditions is the missing link between physics (the science of the inanimate) and biology (the science of the animate—including psychology, the science of mind and behavior). If one accepts the story thus far, biology (exemplified by the stochastic dynamical theory of the finger wagging experiments) conforms quantitatively to a physical (synergetic) picture. But what I am suggesting also here is

[6] After the transition occurs in these experiments, the system is resistant to changes in boundary conditions. That is, its intrinsic dynamics (here referring to the stability of the in-phase mode) resists any changes to the boundary conditions. Thus, even if the participant intended or was instructed to produce anti-phase under the current conditions, he/she could not. It seems like the dynamics in this case—namely at these values of the control parameter—can act back on the constraints. Constraints and dynamics are uneasy bedfellows.

that this description is incomplete, not in any negative sense, but in a 'mind expanding' way that demands an extension of the physical dynamical picture. The argument rests on identifying nonrandom sources of fluctuations that arise due to the special role played by boundary conditions/rate-independent constraints unique to living things (practically and scientifically speaking, in the aforesaid experiments on human behavior). Let me be clear: the stabilizing and destabilizing of coordinated states by "noise-induced" transitions is because the source of additive fluctuations is based on "mental forces", viz., the human subject's intentions (see also [61, 62]).

Up to now, the presumed function of fluctuations is to: (a) probe the stability of coordinated states (as well as being a measure of a state's stability); (b) enable the system to discover new, or at least other coordinated states that suit the current conditions; and (c) enable the spontaneous decision to switch, since after the switching process, fluctuations are diminished/reduced significantly due to the changed shape of the potential or dynamic landscape. A key question, as already intimated, concerns the *source* of fluctuations. This becomes relevant, for example, in light of recent theorizing about the adaptive generation of behavior where they may constitute "unexplained variability" [15, 68]. In HKB, the theory assumes that fluctuations arise because of random noise, of a given magnitude Q and stochasticity ξ_t (but see independent evidence of $1/f^\alpha$ long range correlations in [26], for review, and contributions in [3] as well as the work, e.g., of Chen et al. [7], Treffner and Kelso [76], and Mangalam et al. [58]). Thus, as already mentioned, transitions are assumed to happen due to deformation of the HKB potential, such that the same magnitude of noise has a greater or lesser effect. The fluctuations themselves are not causal. As Haken et al. [24] say: "*It suffices to assume [them] as a random small variable...easily mimicked on a digital computer*" (p.353). That fluctuations hide intention is consistent, however, with work demonstrating the ubiquity of multifractal 1/f noise in many ordinary behaviors. As Chemero ([6], p.82) notes: The mounting evidence that 1/f noise is ubiquitous in human physiological systems, behavior, and neural activity is also evidence that human physiological, cognitive, and neural systems are interaction dominant, which, in turn, is evidence that they are synergies.

A key aspect of the proposition here is that the level of fluctuations depends on boundary conditions, and that the fluctuations themselves are not (or not only) random (though assumed to be so in stochastic HKB). This again is because the stochastic HKB model assumptions do not really coalesce with what is going on experimentally. In the case of the bimanual experiments, for example, fluctuations of the order parameter reflect the participant's ability to synchronize the hands on a cycle-by-cycle basis. A typical cognitive science interpretation views deviations from synchronization in terms of "errors" that the participant produces to achieve the task. Likewise, in the case of the now 'classic' synchronization–syncopation paradigm [48], the cognitive scientist views deviations from perfect performance as timing *errors*. And to be honest, but more for effect, we did too [8]. In Coordination Dynamics, however, such timing "errors" actually consist of voluntary movements made slightly before ("anticipatory") or after the stimulus ("reactive", [14]). Following Synergetics, HKB and the dynamic perspective in general, such "errors" really correspond to *order parameter fluctuations*. The distribution of such fluctuations does not typically take the form of white noise at all (as assumed in stochastic HKB) but, as mentioned above, is $1/f^\alpha$ or scale free. But more important for the present argument is that far from being random, *the fluctuations observed reflect the intentional action of an intelligent agent's attempt to match the environment* with an appropriate action. The fluctuations observed refer to a collective synchronization effect dictated by boundary conditions. The fact that such order parameter fluctuations are scale free suggests not only that they are realized by a highly distributed neural system [8] indicative of synergizing processes (see e.g., [58]) but also that intentional forces are active on all scales.

5 Some implications for mind, matter and movement

I conclude here with some remarks regarding recent theoretical thinking on these issues. According to Froese and Karelin [16]: "To retain the notion of mental causal power means that there are some influences in the dynamics of the brain that cannot be accounted for by the usual assumptions of the theory at play". The idea put forward here, that order parameter fluctuations are a direct reflection of the subject's intentional state in response to rate-independent boundary constraints, may be a candidate for such influences. As the theoretical physicist Sánchez-Cañizares [68] says in reference to HKB: "there seems to be something ontological in that equation that goes beyond its particular realization in physical nature" (p.7). "Particularly... one could have a cycle of phase transitions where the value of the control parameter b and the noise parameter Q are changed by the participant's decision-making". Exactly! Specifically in the Kelso experiments and numerous follow-ups, the parameter Q—instead of mere stochastic noise—can be shown to depend on the adherence (or not) to the boundary conditions "Do not intervene." Thus, although the physical/mathematical model captures/reproduces and even predicts the patterns of experimentally measured fluctuations and provides a dynamical mechanism—the control parameter $\mathbf{k} = \mathbf{b}/\mathbf{a}$ flattens the HKB potential—what actually underpins the spontaneous decision-making process, namely the "real" source of observed fluctuations, is entirely different. They are certainly not random (as the physical model presupposes and reproduces the observed effects). Rather, the source of the fluctuations is determined by the participant's intentional response to instructions. The latter constitute (perhaps rather special) boundary constraints on the decision-making/switching process, but are not contained in the HKB dynamics per se. Sánchez-Cañizares further remarks that "it seems that a simple dynamical model in the spirit of HKB can get the gist of the story... If that is the case, one may still wonder what is behind the change in parameters governing the phase transitions between randomness, metastability and stability". The answer here is constraints, which as Igor Stravinsky was supposed to have said, are liberating. The sources of constraint are well defined in the experiments described here. They are manifold, of course, in the broader scheme of things.

6 Concluding comments

'Letting go' and 'holding on' not only correspond to a subject's intentions in a typical bimanual or sensorimotor experiment but also constitute a key complementary pair of Coordination Dynamics and the complementary nature [43, 44]. Havelock Ellis (1859–1939), the English physician and public intellectual, notably remarked "All the art of living lies in a fine mingling of letting go and holding on". The Nobel Laureate Eric Kandell has also remarked "We live in two worlds at once, and our experience is a dialog between the two". This "interspace" between oppositions (as the philosopher Charles Taylor calls it) is scientifically grounded: it can be shown to fall out of the metastable régime of coordination dynamics [37, 75]. So called "deterministic fluctuations" introduced here distinguish (or unify) the inanimate and animate pictures of the HKB dynamics. In the former, fluctuations are essential sources of stochastic noise. In the latter, fluctuations are functional and purposeful. It is interesting in this respect that in recent studies of the emergence of agency in human babies, fluctuations have been shown to play a variety of roles, such as discovery and exploration, often preceding an 'aha' experience [74].

It is important to note that any discussion of the intentional origin of order parameter fluctuations relies on identifying order parameters or collective variables in the first place. This is one of the many legacies of Haken's *Synergetics* where he showed that instabilities can be used to identify relevant order parameters or collective variables and their nonlinear dynamics on a chosen level of description. In the case of complex systems such as brains and societies, this remains a challenge that may well be worth the effort. In Coordination Dynamics [38] such order parameters or collective variables have been shown to span typical divisions, e.g., between sensory and motor, organism and environment, perception and action, brain and body. The boundary between these separate aspects is blurred to say the least. Like letting go and holding on, the two are intermingled. Order parameters and order parameter fluctuations are *relational*—they exist between body parts, between body movements and sensory stimulation, between brain and cognitive activity, between intention and action, between boundary conditions and dynamics. We want, as Hinton and Sejnowski [27] say, some high-level description of the behavior of the system to remain valid even when the low-level descriptions of the behavior of some of the individual components change. This is only possible, they say, if the high-level description is related to the lower-level descriptions in a particular way: Every robust high-level property must be implemented by the synergistic effect of many local components, and no single component must be crucial for the realization of the high-level property. This was a basic message of Haken's order parameter concept from the get-go [20]. Coordination Dynamics shows that rich dynamic landscapes exist where functional synergies are continuously created and destroyed as intention fluctuates from stabilizing the coordination within the body to stabilizing the coordination between the body and the world. Synergizing cuts across the usual categories and occurs at all scales. Amen to that. Synergetics lives.

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