Nonlinear Dynamics, Psychology, and Life Sciences, Vol. 26, No. 1, pp. 45-79.

Complexity Regulation Competencies: A Naturalistic Framework[1]

Michael Kimmel,[2] *Cognitive Science Hub, University of Vienna, Austria*

Abstract: *This article presents a framework to describe how professional experts regulate complex adaptive systems (CAS), a skill found across bio-psychological, ecological, technical, and social contexts. The regulation aim is to facilitate and constrain the self-organization of a CAS; regulators engage in dynamic decision making while the system evolves. While many naive regulators are overtaxed when they encounter nonlinear and multi-causal dynamics, less is known about how experts perform. I argue that a rich set of competencies can make expert performance distinctive. The basic sensitivities for CAS that shape the general philosophy of practice and a role identity as process facilitators provide some foundation. Turning this into an applied skill set, however, additionally requires (a) the creation of mediating interfaces with a "target" CAS, (b) interaction skills for exploring and stimulating the CAS, (c) the use of domain knowledge about the system's nature and structure for conceptualizing its state as well as dynamics, (d) the use of analogical reasoning, categories, heuristics, and models to make "if-then" inferences from systemic problem constellations to holistic strategies, and (e) synoptic and meta-regulative capabilities that allow supervising the mix of deployed resources relative to the demands of ongoing task. These CAS regulation tools mesh in variable ways and can mutually amplify each other, i.e. synergize. Illustrations for the framework come from two somatic therapies (aka bodywork), the Shiatsu and Feldenkrais methods, in which therapists use manual techniques as a regulatory means to help their clients.*

Key Words: complexity regulation, applied systems thinking, dynamic decision making, embodied and interactive cognition, somatic therapies

---

[2]Correspondence address: Michael Kimmel, Cognitive Science Hub, University of Vienna, Kolingasse 14-16, 1090 Vienna, Austria. E-mail: michael.kimmel@univie.ac.at

INTRODUCTION

The following discussion concerns competencies for complexity regulation in a naturalistic context. I aim to take stock of the involved dimensions of cognition and skill and illustrate them with examples from two therapeutic professions, while integrating research areas that scarcely engage in cross-talk.

Complexity Regulation

Modern-day job descriptions increasingly call upon professionals to regulate complex adaptive systems (CAS) of a biological, psychological, ecological, technical, social, or mixed kind. Experts such as psychotherapists, doctors, epidemiologists, economists, policy makers, emergency aid workers, industrial engineers, or military commanders try to regulate the self-organized evolution of a system (or several nested systems) through recursive interventions and perform real-time decision making for this.

Simulation experiments undertaken since the late 1970s indicate that even many well-educated people struggle with regulating unfamiliar CAS, down to a failure to grasp the system‘s complex nature as such (Diehl & Sterman, 1995; Dörner, 1997; Jansson, 1994). Their difficulties relate to evolving problem states, unexpected emergence, frustrated efforts, delayed or disproportional feedback, side-effects (“you cannot just do one thing”), incomplete information, uncertainty, high cognitive load, and problems with gauging the effectiveness of interventions due to endogenous system dynamics that cannot be factored out easily or due to effects unfolding on multiple timescales. As a system’s dynamic complexity grows, there’s a proliferation of parallel tasks, side-effects, delayed or noisy feedback, unpredictable exogenous changes, and autocatalytic dynamics. The current corona pandemic illustrates the difficulties. Epidemiologists and policy makers are faced with a multivariate problem without a perfect solution, many unknowns, and only gradual discovery of what works, the need to regulate over months and years and to weigh short-term gains against long-term risks, etc. Unsurprisingly, the human cognitive apparatus seems somewhat ill-adapted for regulating CAS dynamics (*bounded rationality*: Feltovich, Spiro, & Coulson, 1997), perhaps because simpler, linear causalities have dominated our lives until quite recently in evolution.

The documented difficulties, however, concern laypeople without special training or much domain-specific expertise. Far less is known about professional experts who may, on average, perform much more convincingly. Think of famed names such as Napoleon as a military genius, Chancellor Bismarck, Winston Churchill or Henry Kissinger as policy makers, Alan Greenspan as an economy wizard, or Moshé Feldenkrais as a myth-surrounded bodyworker. They evidently benefited from decades of experience and possessed rich domain knowledge, enabling them to effectively monitor and

shape self-organizing multi-component systems. Although experts can also fail dramatically, as disasters such as Chernobyl (Dörner, 1997) indicate, successful CAS regulation raises interesting questions about expertise that gracefully deals with causal opacity, nonlinear system behavior, dispersed cues to watch out for, and multi-tasking demands.

Prior Research

The cognitive or socio-cognitive literature on systems regulation is scattered over various disciplines and it is necessary to "combine the best of several worlds" for an overview. In the field of *systems thinking* professionals have been handed useful tools to model CAS dilemmas, e.g., via causal loop diagrams (Lane & Oliva, 1998; Strijbos, 2010), dynamic simulations (Cavana & Maani, n.d.; Sterman, 2000), or system archetypes and their pitfalls (Kim & Anderson, 2007). Related approaches inform curricula for schools (Assaraf & Orion, 2005, 2010; Jacobson, 2000; Jacobson & Wilensky, 2006; Levy, 2017; Levy & Wilensky, 2008), universities (Sterman, 2000; Sweeney & Sterman, 2000) or professional trainings (Fraser & Greenhalgh, 2001; Greenhalgh & Papoutsi, 2018; Nguyen Graham, Ross, Maani, & Bosch, 2012), the idea being that systems thinking can be taught.

Beyond systems thinking itself, actual CAS *regulation* has been addressed by forty years of psychological experimentation (Fischer, Greiff, & Funke, 2012; Fischer & Gonzalez, 2016; Hotaling, Fakhari, & Busemeyer, 2015; Osman, 2010), notably via interactive simulations on tasks such as slipping into the role of a development aid worker, fire brigade coordinator, or city mayor (Brehmer, 1992, 2005; Dörner, 1997; Dörner & Funke, 2017; H. Fischer & Gonzalez, 2016; Funke, 2001; Gonzalez, Vanyukov, & Martin, 2005). This literature has yielded a set of basic rules for effective system regulation, typical errors and "pathologies," factors of task difficulty, and first insights on the decision dynamics. It also proposes, in my view, an incomplete list of cognitive tools. Notably, it neglects interfacing skills with a system and interaction-based problem solving, perceptual skills as well as supervisory functions, and leaves much open about the role of domain knowledge. Later sections will address each of these issues.

It has been rightly emphasized that CAS regulation operates as dynamic coupling in which a person uses feedback from the target system (a therapy client, group behavior, a technical array, an ecology, etc.) and feeds information and actions forward into it. The coupled loops between system and regulator necessarily presuppose "reflection in action" (Schön, 1991) and sensitivity to emergent effects. In this task constellation, strategizing in advance is, if at all, possible in very sketchy ways and is best conceived of as imposing constraints and general directions on CAS dynamics, as opposed to "planning." Researchers thus have coined the term *dynamic decision making* (DDM; Brehmer, 1992; Gonzalez et al., 2005, 2017; Hotaling et al., 2015), in which "a series of actions must be taken over time to achieve some overall goal, the actions are interdependent so that later decisions depend on earlier actions, and

the environment changes both spontaneously and as a consequence of earlier actions" (Hotaling et al., 2015; p. 709). Hence, the problem state itself evolves constantly. In DDM solutions emerge path-dependently, and that the state of the system needs to be explored while already acting (Maani & Maharaj, 2004). DDM research is an important player in studying how CAS are ongoingly regulated, yet still a relatively small field.

Other research addresses mental models used to support decision making (Gary & Wood, 2016). In addition, preliminary findings on the dynamics of iterative reasoning (Maani & Maharaj, 2004), and cybernetic process control models (Brown, Karthaus, Rehak, & Adams, 2009; Richardson, Andersen, Maxwell, & Stewart, 1994) bear mention. Much can also be learned from expertise researchers who address ill-defined dynamic decisions tasks in which cognitive and task complexity – albeit not CAS complexity – are at issue. In the field of naturalistic decision making (Crandall, Klein, & Hoffman,, 2006; Klein, 1998; Klein & Hoffman, 2008; Lipshitz, Klein, Orasanu, & Salas, 2001), the framework known as *data-frame modelin*g (Moore & Hoffman, 2011) deals with ongoing assessments and strategy updates close in spirit to the basic assumptions of the DDM field. Research from cognitive ergonomics and human factors (see Guastello, 2014) additionally addresses coping with uncertainty, as well as ways to make systems resilient and to manage emergent occurrences (Guastello, 2002, 2016; Osman, 2010).

The CAS Regulation Framework

This section introduces a framework of competencies employed by experienced CAS regulators, which cut across cognitive, perceptual and action capabilities. Since regulating (bio-psychological, ecological, technical, or social) CAS ranks among the most demanding tasks humans have to cope with, a rich cognitive ecology is needed. Thus, applied CAS regulation can only happen by co-orchestrating *multiple* abilities, none of which suffices in isolation and whose respective constraints typically produce trade-offs.

Figure 1 surveys different types of competencies and their interplay: The most basic prerequisite for CAS regulation is a general complexity mind-set, which sensitizes to what complexity means and shapes the experts' role identity and general perception of their task (*top tier*).

Next, mediation skills for connecting with the target CAS and skills for assessing system states are needed. This can, for example, benefit from creating resonance with the target CAS and from embodied skills to interface with it effectively. In particular, the ability to assess a system at a given moment commonly draws on embodied and interactive reasoning processes, which are used to explore and stimulate the target CAS in strategic ways (*top left*).

Professional experts – in sharp contradistinction to naive subjects in CAS regulation experiments – possess rich domain-specific knowledge about the nature, appearance, and structure of the system they are supposed to regulate (cf. Shanteau, 2015). This knowledge usually combines theoretical knowledge

with prior practical experience; it supports CAS reasoning in multiple ways, for example by informing assessments of a systemic problem constellation or by guiding predictive system simulation (*bottom left*).

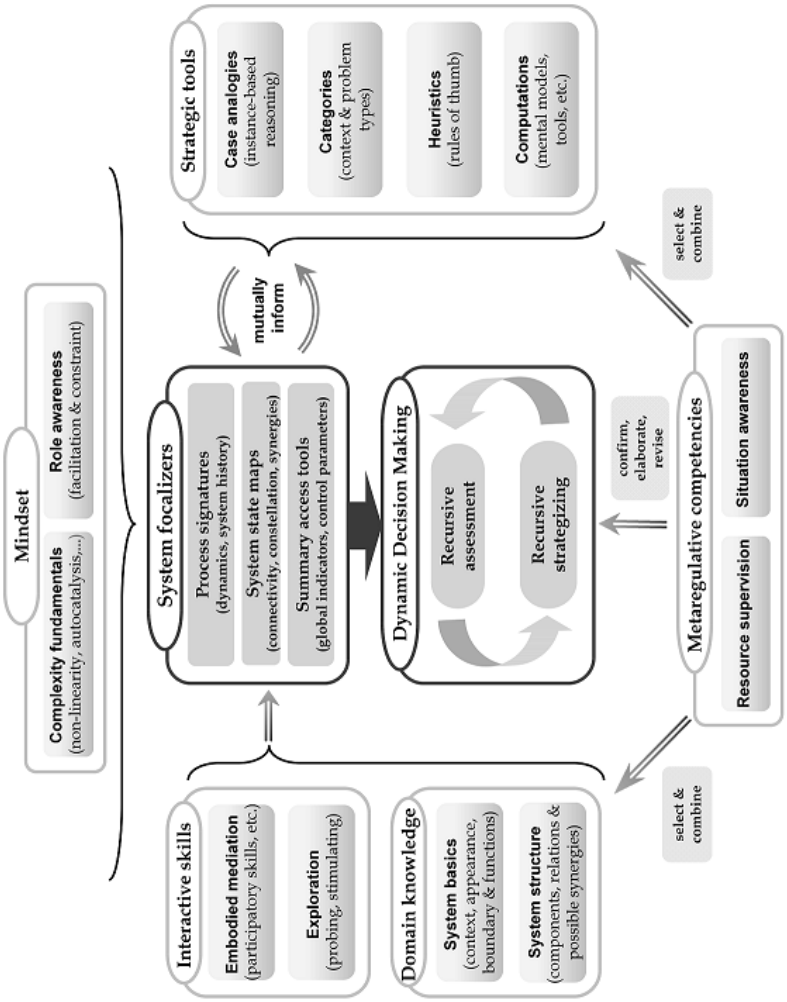

Fig. 1. Regulating a complex adaptive system: resources and process flow.

Based on this active system monitoring and probing CAS regulators try to understand the systemic problem constellations they currently face. They may create mental snapshots of system states, "read" system dynamics, or use summary indicators and levers for system-wide regulation (*center top*). Comp-

lementarily, finding a coherent strategic approach to CAS regulation typically draws on specialized reasoning tools. These can include context and problem categories, heuristic rules-of-thumb, computational models, as well as the ability to connect a problem to past experience through analogy building (*right*). Since all of this requires a temporally extended DDM process, reasoning is realized through recursive cycles of active engagement in which assessment and action are braided. Reasoning thus evolves as a back and forth movement between (often sketchy) strategy constraints and recursively updated system and task evaluations (*center*).

Finally, experts possess a set of integrative and meta-level skills to supervise how all these tools are mixed and balanced to "hold everything together." This involves synoptic situation awareness and what I shall term process meta-regulation, two interrelated facets which are arguably one of the hallmarks of high-level expertise (*bottom*).

All of this flows into a regulation process in variable ways. The competencies and resources can be thought of as a *meshwork* (Ingold, 2011; cf. Kimmel, 2017), which can be combined "on demand" and flexibly adapted to the situation in different modalities (cf. Hoc & Amalberti, 2007). Therefore, the elements of the competency set cannot actually be compartmentalized; their meshing is typical for situated practice and, indeed, many regulation challenges require them to support and amplify each other. For example, skilled perceptual procedures that specify how to explore the CAS frequently synergize with structural system knowledge which specifies which relations in the system to explore.

In the remainder of the article I will discuss these competencies, based on how expert CAS regulators describe processes and their expertise. Although I primarily aim to expound a framework which applies across different professional contexts, it is expedient to use exemplifications from a domain in which this framework first emerged. Specifically, I draw on qualitative data from two health professions that regulate a client's somatic system via "skin-to-skin" interaction. These somatic therapies are known as Shiatsu and the Feldenkrais methods. To understand CAS regulation competencies naturalistically, my colleagues and I employed an incident-based research design: Several experts were interviewed about specific therapeutic processes and the competencies they used. Two expert-scholars additionally kept a practice diary that was later analyzed. For details on methods and the domains I refer the reader to (Kimmel, Irran, & Luger, 2015; Kimmel & Irran, 2021). It should be noted that that a large amount of work on CAS regulation comes from a somewhat related domain inspiring our work, to which this article refers repeatedly, psychotherapeutic process research (e.g., Haken & Schiepek, 2010).

Somatic Therapies

To give the reader the necessary minimum of domain context, it is helpful to sketch what happens in the somatic therapies Shiatsu and the

Feldenkrais Method. Somatic therapies are variously characterized as complementary and alternative therapies or bodywork, the term I use here (the wider family of bodywork therapies includes Osteopathy, Physiotherapy, Rolfing, Alexander Technique, Tuina, and many others). Bodyworkers apply manual techniques to the client's body; some of them add energy work, breath work, or imagery exercises. A Shiatsu and Feldenkrais session occurs in a one-on-one context. A therapist treats a client in lying, sitting, or standing position. The aim is to advance the client's well-being via mindful touch, for which the therapist's presence, embodied empathy and responsiveness are employed in a continuous embodied "dialogue," as bodyworkers would often say. A session typically begins with a verbal anamnesis; then the therapist physically attunes with and examines the client. Next, a combination of manual techniques is applied over 30 minutes or more. An integration phase may be added towards the end.

The focus of the Feldenkrais Method lies on issues overcoming inefficient or strained movement habits and neuromotor learning through improved body awareness. In the interaction between a "teacher" and a "pupil" (i.e., a client), an approach known as *functional integration*: gentle, slow, and repeated movements of the client (active or passive) as well as subtle explorative stimulations through non-directive touch are used. A key idea is to differentiate movements before re-integrating them, as well as using minimal stimulus differences (Rywerant & Feldenkrais, 2003).

Shiatsu aims to harmonize the client's energetic organization, primarily using massages or stretches and applying acupressure on energy pathways known as *Meridians* which run on the surface of the body (Palanjian, 2004). To determine treatment aims and strategies Shiatsu uses concepts from Eastern medicine (many of which clash with how current biomedicine thinks, but which orient the therapist's actions anyway). Both bodywork domains provide us with excellent examples of CAS regulation:

1. The two domains both exhibit a systemic orientation (Buchanan & Ulrich, 2001; Kimmel, Irran, & Luger, 2015), with a philosophy that holistically aims at what is frequently termed bio-psycho-social well-being. Therapists accompany the client through a systemic re-organization process. While Shiatsu addresses a wide range of organismic issues to begin with, Feldenkrais has a somewhat narrower treatment focus on the movement apparatus and inefficient habits, yet often also enhances better functioning in other aspects of life.

2. Since bodywork is an interactivity-based form of therapeutic intervention (as opposed, for example, to an acupuncturist, who leaves the client after setting the needles), therapists need refined DDM abilities for "reflection in action." They continually develop their strategy and update their system assessment. As interventions are combined over time, client responses are monitored and therapists stay adaptable and receptive to the feedback in this process. This puts therapists into a position to select manual techniques or adapt their mix and their strategic priorities within the process; even key objectives of a session may emerge underway as the diagnosis is recursively refined.

3. Bodywork is noteworthy for the close entwinement of regulator and target system. The interpersonal system of embodied communication between therapist and client, a CAS in its own right, is used to address the target CAS, the client's health. (Of these two nested CAS the interaction supplies a means to address the client.) I return to the importance of skilled communication with a target and competencies situated at that particular level in a later section of this article.

COMPLEXITY MINDSETS

After this introductory sketch we can begin to discuss details of the various aspects of the CAS regulation framework. Following the scheme of Fig.1, fundamental mindsets sit at the top, which frequently precede the more sophisticated reasoning and regulation skills, but which, in and of themselves, remain relatively general. This top level commonly involves fundamental sensitivities for complex systems, a philosophy of practice, and ideas about the general "job description" of a CAS regulator.

Task Awareness and Philosophy of Practice

Professional discourses are often complexity-sensitive in highly particular ways. Exploring the nature of these sensibilities is instructive for scholars, because they reveal (a) what the perceived nature of the CAS regulation task is and (b) which kinds of systemic thinking are common and taught by masters to novices. To illustrate, in our two bodywork domains the recognized CAS regulation task set-up is such that dysfunctions of the client's system need to be transformed into a balanced dynamic disposition, which displays resilience and responsiveness to contextual demands. The therapist's task is to enable, constrain, and accompany the client's systemic self-organization in a sustainable fashion, a CAS regulation aim that is typologically somewhat different from many other settings (e.g., economic, ecological, military). How the target system is conceptualized reflects this: Bodyworkers think of bodies as CAS that self-organize to exhibit, among other things, homeostatic properties such as metabolism. Under this view, health is tantamount to a well-organized interplay of components whereas illness or strain reflects a lack of systemic adaptiveness in that respect.

Accordingly, bodyworkers do not necessarily attribute the client's complaints to local dysfunctions of specific components; rather many problems are seen as network-related. For instance, back pain may arise because the iliopsoas muscle on the body front is strained. The client is caught in a malign network constellation that can become self-sustaining or even chronic. This also makes a "fix" at a local scale unwise, since network problems tend to remain unresponsive or bounce back (i.e. non-reactance). Thus, bodyworkers typically look for ways to effect a dispositional re-organization in the entire systemic network.

This philosophy of health mirrors complexity-theoretic insights about biological and interpersonal CAS (Bell, Koithan, & Pincus, 2012; Fogel, 2013; Haken & Schiepek, 2010; Koithan, Bell, Niemeyer, & Pincus, 2012;

Pincus, 2012; Pincus & Metten, 2010; Strunk & Schiepek, 2014; Tschacher, Dauwalder, & Haken, 2003; Tschacher & Grawe, 1996; Weiss, Qu, & Garfinkel, 2003) as well as holistic medicine, which thinks of somatic processes as self-organizing CAS, defines health as well-being/resilience, and has proposed various complexity metrics as well (Godin & Buchman, 1996; Goldberger, 2006; Sabelli et al., 2005; Sabelli & Lawandow, 2010; Vargas, Cuesta-Frau, Ruiz-Esteban, Cirugeda, & Varela, 2015).

Role Awareness

I would now like to discuss some general facets of the basic complexity mindset that bodyworkers likely share in common with most of CAS regulation professions, although the details and possible smaller differences remain an interesting inquiry for the future. It is a direct consequence of seeing the target system as self-organizing CAS that a specific professional self-perception arises. Regulating cannot be "controlling" of "fixing" (cf. Osman, 2010). The job can only be process facilitation, where one's role is one of accompanying and enabling, buffering and channeling, as well as setting global constraints for the target system. In the two bodywork domains discussed in this article, therapists often prefer to realize this through a specific philosophy of practice, namely by encouraging and, often gently or indirectly, inviting transformations, while respecting autonomous processes. They often see their task as facilitating or enabling the client's *self-organized learning*.

Bias Awareness

Awareness of complexity pitfalls or "pathologies" (Jansson, 1994) tends to arise from a confrontation with the typical task pressures of complex domains (multi-causal problems, goal conflicts, side-effects, feedback delays, multiple intervention foci, uncertainty, hidden variables, and the absence of a single "correct" solution). The way the target system responds quickly calls into question biases that govern much everyday thinking. Notably, the belief that systems are typically centrally controlled is replaced by network-based views of autocatalysis and the assumption of *multiple*, *reciprocal*, and *circular causalities* between variables. Other biases that are overcome include the intuitions that "the available information is representative of the actual state of the system" (Brehmer, 2005, p. 88), that causes and effects are related in a one-to-one manner such that temporally close cues are also causally associated (Osman, 2010, p. 193ff), and that trends are linear (a view that leads to underestimations of exponential growth and related dynamics).

Whether or not these sensitivities are expressed in explicit verbalizations, they become manifest in the practical and psychological behavior of experienced CAS regulators who remain unfazed when an intervention meets with no immediate reaction (i.e. the system's staying power), when feedback is delayed or seems "out of place," when nonlinear effects such sudden leaps or fluctuations happen, and when the size of an interventions and the effects are far from proportional (cf. Goldberger, 2006). Since, small actions can have great

consequences and large actions small or no effects, CAS regulators may often learn how to work with well-timed minimal stimuli or combine them in clever ways.

Another practical consequence is getting used to causal opacity. In particular, the idea that "effects are effects of my actions" is not applicable; neither successes nor failures are necessarily one's own doing. This in turn warns against jumping to conclusions about whether a causal assessment or a strategy are appropriate. Yet another practical consequence is that, since actions seldom have a single effect only, one needs to keep the whole system in view – misallocation and narrowing of attention is a common source of error in inexperienced CAS regulators (Dörner, 1997).

INTERACTIVE SKILLS

A much neglected topic in past accounts of CAS regulation concerns the informed and skillful ways in which regulators mediate the information exchange with their target system and establish an appropriate set-up for this. This is an essentially embodied factor, even in domains that seem less embodied than our present examples.

A central lesson from so-called post-cognitivist approaches (Robbins & Aydede, 2009) is that human cognition and action should not be accounted for as internal computations, performed irrespective of one's body, handling skills, tools, or resources found in the current environment. Taking this to heart is crucial for CAS regulation, which invariably depends on the specific material communication medium of the task, requires specific attentional and physical skills or habits, and typically exploits situated resources for reasoning, rather than "thinking through" a systemic problem in an abstract, generalizable way, as the adherents of the traditional computational view would assume. To capture this special facet, I explain *embodied mediation (or interfacing) competencies*, which CAS regulators must acquire and which are a crucial site for explaining why certain regulations succeed and others do not. Mediation skills are arguably highly domain-specific and may involve interacting with tools, machines, computers, structured work environments, and specially create group configurations (Hutchins, 1995a).

Embodied System Participation

Skilled mediation may often take the form of resonance with the system (Raja, 2018). Some cognitive scientists have emphasized that in social systemic constellations there can be *participatory forms of sense-making* (De Jaegher & Di Paolo, 2007; see applications in Kimmel et al., 2015; Øberg, Normann, & Gallagher, 2015; Röhricht, 2009), where the interpersonal coupling becomes an operationally closed system exhibiting its own self-organizing dynamics. In a CAS context this implies that the regulator is in fact a part of the system and sets its control parameters from the inside (Keijzer, 2003). Arguably, a participatory account like this might even be extended to how experts in CAS regulation

connect with their tools, enabling workspaces, or resonances with the external situation. This is not to say, however, that ecological or economic CAS regulation, which seemingly operates more from the "sidelines," is fully like our present example.

Bodywork therapists in Shiatsu and Feldenkrais, in any event, emphasize their participatory approach. A first implication is that the participatory modality is a locus of skill investment: Clients benefit just as much from the "art of encounter," i.e. trust, empathy, and presence, as from massages, stretches, or mobilizations. Through the immediate tactile-kinesthetic interaction a shared physical medium is created, a state of *mutual incorporation* (Froese & Fuchs, 2012), where the therapist's CNS and sensorimotor system literally extend into the client. This domain-specific regulation set-up provides for a highly responsive "resonance loop" which allows bodyworkers to monitor and optimize or repair the process continuously. It enables rapid and rich access to information, and allows keeping input exceptionally close to the interaction dynamics (see *dynamic immediacy* in Kimmel et al., 2015; Kimmel, Hristova, & Kussmaul, 2018). Depending on how the client assimilates a particular stimulus, the bodywork therapist can momentarily determine when to repeat or adapt an input, when to wait, merely accompany, or decisively stimulate, etc.

This "dance of two nervous systems," as Moshé Feldenkrais, the founder of the eponymous method, once called it, lets therapists literally partake in the dynamics of the target system and makes the modality of interaction a powerful tool. The encounter itself, for example, by utilizing joint breathing with the client, becomes as a transformational means. Similarly, psychotherapy researchers have emphasized the power of transactional effects in a two-person system (Seligman, 2005) based on "a nonlinear communicational field where meaning is dynamically co-constructed by means of social and intersubjective (re)negotiations between the client and therapist" (Gelo & Salvatore, 2016, p. 381). An optimized coupling modality is a well-documented unspecific effectiveness factor and may even constitute the prime source of sustainable change (Strunk & Schiepek, 2014). The participative modality thus provides global conditions for sustainable and self-organized system transformation (Haken & Schiepek, 2010).

Scholarship needs to analyze the skills involved in establishing and utilizing this particular CAS regulation set-up: This "art of encounter" involves establishing trustful rapport, an acceptant attitude, creating a safe space, and attuning to the client's dynamics. Empathy, continuity, mindful touch, attuned breath, and voice modulation can greatly enhance the client's participation and receptivity. The regulation set-up also involves preparing information channels that can pick up on the relevant input and exploit an embodied resonance field between the bodies. Bodyworkers can use this to explore and sensitize the client's system and modulate, constrain, buffer, or amplify ongoing processes.

In addition, utilizing resonance as a means of regulation always requires a feel for how exogenous stimulation meaningfully blends with the

target's endogenous dynamics and adapting this at each moment. To take an example from Feldenkrais, a therapist may assist a client's with a stiff leg to move it to the precise extent that this creates ease, but still engages the client's sensorimotor system actively.

Another skill concerns what we may call *process competency*. For channeling the client's endogenous dynamics a knack for tipping the system is of great value when a saddle between two attractors is reached, at which point the client can be helped to choose the more beneficial side (*symmetry breaking*). In psychotherapy research, the importance of learning to identify these decisive moments has been discussed; possible indicators can be critical fluctuations or slowing down of dynamics (Schiepek, Tominschek, & Heinzel, 2014). Process competency can also mean encouraging clients to relax into chaotic dynamics at certain points, rather than counteracting them, as suggested by research in the bodywork field called *neurophysics therapy* (Ross & Ware, 2013). In keeping with this, bodyworkers in Shiatsu and Feldenkrais report that they notice when an auto-catalytic process in a client sets in, enabling them to dampen overshooting dynamics or amplify hesitant transformations. They also report that if chaotic looking patterns are perceived they can wait to see if a trend crystallizes and if not, take the lead.

Interactive Reasoning

It can be said that recursive and intertwined reasoning processes form the basis of all DDM. Picturing CAS regulation as anything like a serial, well-structured process would be a mistake. In this regard a major oversight in CAS regulation research concerns the vital role of "reasoning by acting in the world." Regulators invest in interactive strategies for effective situation assessment and reasoning. Interactive mechanisms are quite pervasive in human cognition, including professional contexts of recursive "reflection-in-action" (Schön, 1991). The vital importance of active engagement for reasoning, problem solving, and creativity has been empirically explored by post-cognitivist cognitive science (Kirsh, 2009, 2014; Steffensen, 2013; Steffensen, Vallée-Tourangeau, & Vallée-Tourangeau, 2016). Doing is then literally a form of reasoning, which offloads functions from the mind to active engagements with the world (Kirsh & Maglio, 1994). Theories that emphasize interactivity in this way debunk the traditional "sandwich view" (Hurley, 2001), which defines perception and action as peripheral functions and subscribes to a serial input-output view. Interactivity theorists reject the assumption that "thinking" in the mind is the central function, or that we can simply relegate the senses to a mere delivery systems and the action system to an implementation device. Instead, embodied and mental functions are functionally braided in recursive loops and constantly inform each other.

Bodywork professionals provide excellent examples of reasoning that is facilitated by recursive engagement (Kimmel et al., 2015; Normann, 2020; Øberg et al., 2015; Kimmel & Irran, 2021). A bodywork treatment parallelizes

and braids diagnostic ("perceptual") with intervention ("action") functions. Although there is a diagnostic phase at the outset of a session, interventions remain implicitly diagnostic and allow the expert's assessment to be progressively refined or revised continuously. The interactive strategies of bodyworkers range from playful exploring to particular diagnostic stimulations and calculated micro-provocations. Many strategies are dynamically specified while acting and by learning from the feedback. Strategies may be interactively customized in this way, e.g., actions are modulated or a technique is added if desired effects remain absent. Simply "entering the fray" can allow figuring out what to do next as one goes along (as in Napoleon's famous "*On s'engage et puis on voit*"). Often this starts by applying techniques such as muscle flexibilization or joint massages, which "never hurt," and then paying attention to feedback that arises. Bodywork therapists may even determine treatment goals based on the emergent feedback or issues noticed underway. This kind of interactive approach has the added benefit that is stays open to serendipity and can react to emergent effects or alarm signals any time.

Embodied System "Querying"

A tremendous range of embodied skills are needed to assess the target CAS in effective ways. This involves a broad set of domain-specific techniques for active perception, the importance of which is by no means a special feature of somatic contexts, although it is particularly pronounced here and a special subject of instruction.

In bodywork, perceiving the client's system, far from passive information pick-up, is a context-sensitive activity of exploration and "querying" with the hands or letting the gaze wander. This takes skilled forms of palpating or scanning the body and can often happen in cumulative (rather than "one shot") ways, such that multiple local percepts add up to a gestalt impression (cf. Higgs & Jones, 2000; Klemme & Siegmann, 2015; Wallden, 2012). In addition to verbalized complaints, the client may be checked for postural alignment, warped body lines in walking, strain, body parts that unnecessarily "tag along," stereotypical reactions despite context changes, limited ranges of motion, perceptions of heat, skin color, hardened muscles, breath stagnation, and the distribution of excessive or depleted energy over the body (the latter only in Shiatsu). Furthermore, a therapist's active "querying" can reveal where information flow is stalling and where sub-systems keep each other in check or overexcite each other.

Furthermore, activating or stimulating the target system is a vital assessment tool. That is, interventions are applied not only for effect, but also to generate feedback and observe the system's feedback loops "in action." This can happen through well-chosen subtle inputs or diagnostic queries cleverly packed into full-scale interventions (since the hands are both sensors and effectors at the same time). Bodyworkers may use their hands to co-activate several physiological components in order to test if they communicate enough and react

in mutually adapted ways. Multiple components (e.g., muscles) partaking in a complex physiological function are checked for individual viability, adaptations when a connected component changes, and whether they function as a well-coordinated ensemble. Furthermore, obstructions in the system can be tested by checking system pathways along which impulses should propagate in healthy people. Feldenkrais experts frequently use a reactivity analysis in which they direct force into a skeletal line to test whether it reverberates throughout the body or becomes "smothered" along the way. Yet another way to see how a system creates activations is to simulate a task with the therapist's assistance. Walking on a floorboard in lying position is sometimes used in Feldenkrais, as a gravity-free, but otherwise natural coordinative task. All these active techniques are crucial to distinguish genuinely systemic (i.e. network-based) causes from local problems affecting only a particular component.

Evidently, the kinds of explorations relate to the domain-specific idea of what adaptive system behavior means. When Feldenkrais therapists test system habits for organic movement they check whether components of a task create what movement science would call a coordinative structure or synergy (Harrison & Stergiou, 2015; Latash, 2008), which should be both variable and context-sensitive. Unwanted "parasitic" co-participations or components that connect regardless of context are just as much of a problem as components that refuse to connect at all. Thus, stereotypical responses, isolated parts, or ensembles performing only a single function may indicate systemic dysfunction.

DOMAIN KNOWLEDGE

On top of specialized perception and action skills, the fact that professionals command a rich and sophisticated domain-specific *knowledge base* makes a massive difference to the context adequacy of CAS regulation. This and the next section will discuss how different kinds of specialized knowledge infuse expert reasoning about a CAS and actions to be taken.

Basic System Knowledge

To begin, effective CAS regulation presupposes understanding the target system generically. This involves understanding the system boundaries, functions, dynamic forms, as well as approximate problem appearance and type (e.g., do you expect delayed feedback, what is normal and what cause for alarm). In this respect a CAS where keeping a homeostatic balance is the central aim differs from one with transformative regulation aims. CAS can also differ with respect to how precise or fuzzy system boundaries are, how invariant the external conditions are, how rapid the dynamics are, or how many regulation aims must be pursued in parallel. It is the basic connectivity degree and feedback loops of the system (Strunk & Schiepek, 2014) and the range of possible emergent effects that define the scope of CAS regulation.

In professional contexts these fundamentals may be largely familiar from prior experience, teachers, and textbooks. Some specifics such as the

system boundary may, however, be in need of being determined in every particular case. In bodywork, it needs to be checked whether psychosocial factors such as stress or worries may play a role, or whether chronic and dispersed problem causalities may be the case. Or, it may need to be ascertained what functionalities the sensorimotor system commonly needs to perform, say when a professional violinist reports shoulder and neck pain.

Basic Regulation Virtues

This basic system knowledge can inform a set of general regulation virtues for the specific type of CAS. A domain-specific, but in part also generalizable, digest has been discussed by the synergetics framework of Haken and Schiepek (2010, p. 436) under the rubric of so-called *generic principles*, which are formulated as ideal norms for facilitating therapeutic transformations. Generic principles are held to include the following: (a) creating stable framing conditions, then destabilizing the system to transform it; (b) determining system status and boundaries; (c) ensuring that new experiences cohere with the client's aims and are experienced as a synergistic whole; (d) energizing the client's system for self-organization, e.g., through lifting inhibiting blockages or by ensuring client motivation; (e) destabilizing or interrupting unfavorable patterns and amplifying spontaneously occurring deviations; (f) synchronizing with the client and presenting new input when the system is open to change; (g) helping the system when it stands between different possibilities, i.e. in a state of symmetry, to move into the right direction, and (h) enabling or assisting the system's restabilization after shifts. These precepts are meant to provide a set of general criteria, although they say little or nothing about specific realizations yet. A particular therapeutic technique can frequently contribute to different of these generic principles and, conversely each principle may be realized in multiple ways (Schiepek, Schöller, Carl, Aichhorn, & Lichtwark-Aschoff, 2018). These generic principles are also general enough to carry over really well to Feldenkrais and Shiatsu settings, where experienced therapists think in similar terms (Kimmel et al., 2015).

Structural System Knowledge

A more specific kind of expert resource is referred to in CAS regulation studies as *structural knowledge* (Schoppek, 2002). It requires familiarity with system components, their appearance, their locations, their functional network connections and feedback loops, as well as how component interplay performs certain dynamic functions. Structural knowledge works hand in hand with several other competencies. For instance, exploration procedures which specify *how* to perform system assessments require structural knowledge that specifies *where* to explore and which system locations to monitor.

Bodyworkers, specifically, employ structural imaginings of human physiology and anatomy which represent the external appearance and location of limbs and organs as well as the functional interplay between the different body

elements. In Shiatsu various layers of the organism (myofascial, skeletal, energetic) may be focalized; in the Feldenkrais method structural conceptualizations crystallize around bone configurations. Basically, structural network features are visualized as a "body map" and as a grid of connections or pathways. This body map, furthermore, defines how parts should connect for various ensemble functions, e.g., a muscle chain that is topologically connected implies that the muscles along this particular strand work together in a task such as lifting an arm. Assumptions about co-functionality thus become associated with the topological features defined on the map. These component interactions are often dynamically imagined. Kimmel and colleagues (2015) argue that therapists may imagine both the specific horizontal relations between components and the vertically emergent higher-level functionalities when a task is performed. In the hierarchy, these ensemble functionalities can range up to functions emerging from the interplay of entire physiological sub-systems.

Acquiring such structural knowledge can involve years of training. For example, Feldenkrais training begins with self-experience for a year, then learning to perceive and interact with clients with a focus on local anatomy; only in the last two years do trainees learn to attend to system relations and conceptualize structural-functional features.

During a therapeutic session, structural-functional imagery of the body augments the expert's perception of the momentary CAS state. In other words, bodyworkers may project structural images such as skeletal lines into what their hands and eyes currently perceive. This helps to evaluate hidden properties underneath the skin such as the position of an inner organ. Structural imagery also focalizes attention while using exploration or stimulation techniques, as well as while monitoring the client's responses. For example, information search in Shiatsu may concentrate on one suspected pathway (i.e. *Meridian*) and diagnostic hypotheses with respect to the causal role of this pathway can be verified in a focused fashion.

Overall, structural-functional knowledge facilitates the CAS regulation process in two ways: It directs perception to what actually matters most about a CAS according to the professional state-of-the-art. Thus, in Shiatsu diagnostic explorations happen via palpation of *Meridians* as well as diagnostic procedures on specific locations of the belly known as *Hara diagnosis*. Secondly, structural-functional knowledge provides a crucial yardstick relative to which bodyworkers identify system dysfunctions. As shown earlier, evaluations of good alignment and postural features, well-coordinated movement, energy profiles across the body, and all manner of mutual responsiveness and adaptive interplay between components are based on structural-functional images of what a healthy body system appears like.

SYSTEM FOCALIZERS

To take stock of where the argument stands it may be said that embodied interactions with the target CAS involve particular procedural skills,

which receive guidance from domain knowledge. Let us now systematize once more in which respects this informs CAS assessment: We can subsume the various structural, dynamic, and "global access" aspects of system assessment under the heading of *system focalizers* that an expert CAS regulator keeps on the radar and updates as the regulation process proceeds.

State-Maps for Connectivity and Inhibition-Excitation

To conceptualize the momentary state of a CAS, experts must select salient dimensions and picture their connectivity in what I call a *state map*. Its purpose is to evaluate component interactions with respect to whether they currently synergize, compete for resources, block or weaken each other, or are even caught in some vicious circle. In the literature, it has been argued that connectivity tests may include judging the direction and weights of component interplay, as well as possible delayed reactions (Gary & Wood, 2016). On the basis of connectivity tests, sophisticated forms of diagnostic reasoning about information flow and about inhibition or excitation between system components can ensue. In Shiatsu, diagnostic assessments focus on notions of mutual depletion, inhibited circulation, flow strength, or imbalances between components. These diagnostic assessments are developed within a framework where adaptive energetic relations in a body, as defined by traditional Chinese medicine, are conceptualized as patterns of "nourishment" or "control" between physiological sub-systems (which are named after body organs such as lung, spleen, gallbladder or liver, but need not match the respective biomedical organs). In Shiatsu practice, these interplay patterns lie in the focus of a comprehensive diagnosis since they allow therapists to identify both root causes of systemic problems and effective control parameters (see below). Thus, when a body sub-system shows a manifest hyperactivity or deficit the therapist may need to reason back to other sub-systems, whose perhaps less salient dysfunctions are causally implicated. The diagnosed interrelations are often binary such that a depleted sub-system corresponds to an over-active counterpart. In other cases, triadic or even more complex constellations are involved in this diagnostic reasoning, such as vicious circles involving three subsystems.

Process Gestalts and Dynamic Signatures

Dynamic signatures of system behavior provide important focalizing information. These are termed *process gestalts* in the literature (Haken & Schiepek, 2010; Tschacher, 1997) and may involve, e.g., paying attention to intervals, fluctuations, pattern recurrence, fractal similarities across timescales, or how chaotic a process is. A sense for process gestalts helps therapists to take stock of preferred and non-preferred dynamics in a client, thus providing information about intrinsic system dispositions. Therapists frequently check system stability by testing how easily it returns to its initial state after small perturbations. They recognize the significance of particular process signatures,

such as fluctuations that tend to herald system transformations, "healthy variability" patterns (cf. Pincus & Metten, 2010; Vargas et al., 2015; Woods, 2006), flushes of sudden excitation, subsiding resistance to change, the beginnings of reorganization dynamics, and so forth. There are even indications that system entropy can be subjectively perceived. Furthermore, bodywork therapists often report paying attention to initial conditions and paths that led to the present state. This sensitivity for interaction history (*hysteresis*) is a feature that is known to be important for CAS regulation (Haken & Schiepek, 2010). Different aspects that this includes are further discussed below in the sub-section "Situation Awareness."

Summary System Access

CAS regulators use tools for gaining global access to the target system One of these are so-called *indicator variables* (Dörner, 1997; Vester, 2007). This refers to variables known to allow a quick "system report," which indicates if a system is globally thriving, moving in a good direction, on the verge of turning precarious, temporarily unsound, or chronically dysfunctional. Indicator variables are components of a system that respond to many other variables without being very influential themselves, so they provide a good index of the system's current overall state. For instance, bodyworkers know that the client's muscle tone and voice provide indicators of stress. Inversely, signs of a parasympathetic (relaxation) reactions are monitored such as free and deep breathing or slower, more constant heart-rate. How lively the eyes are is another indicator.

Complementarily, certain powerful means of regulating the system globally are "kept on the radar." Complexity science refers to these as *control parameters*, to which the CAS's self-organization is globally sensitive (including control parameters that destabilize the system and are best avoided). In bodywork basic control parameters such as trust, presence, active participation were previously mentioned, which are known to experts as part of their general domain knowledge. Beyond this, the skilled identification of situation specific control parameters is a recognized expert skill (Schiepek, 1986, p. 198). Finding out which parameter a CAS responds to most readily in a specific problem constellation can, for example, help break a vicious circle. In a psychotherapy context, diagnostic diagrams have been proposed to identify such control parameters (Schiepek, Eckert, & Kravanja, 2013), which are generated through an one-hour interview with the client.

General Functionalities

System focalizers supply various functionalities, beginning with the facilitation of attention management. That is, having salient system aspects "on the radar" helps CAS regulators to effectively shift attention between components and their global interplay. For example, by moving attention between parts and wholes bodyworkers monitor whether and how changes at the local level impact emergent system behavior. System focalizers therefore are

important for monitoring transformations in progress. Bodyworkers pay attention to connectivity shifts. They notice when components begin to reconnect into a previously suppressed function, when new players become active in the system, how improvements in the interplay of components make new synergies emerge (e.g., when skeletal lines align the ability to take weight can suddenly arise), as well as noticing improved qualities in specific locations.

Next, system focalizers allow a collective interpretation of the current constellation. Macro-scopic condensations can be created of how variables connect and what patterns emerge (somewhat related to a "forest" view" proposed by Maani & Maharaj, 2004). At a middle level of abstraction, the gist of a systemic issue is captured by domain-specific concepts such as in Shiatsu the notion of "Weak Kidney Ki" or the Feldenkrais idea of "unwanted parasitic movements." On the other hand, a gist-like conceptualization of the current constellation may reflect more abstract *system dynamic archetypes* (Kim & Anderson, 2007) such as "competing system tendencies," "vicious circle," "problem propagation chain," or "change buffering and relapse." Inversely, expert reasoning may conceptualize pitfalls such as "purely symptom-oriented actions," "unintended consequences of a problem fix," or "short-term gain for a long term cost" (cf. Kim, 2000; Kim & Anderson, 2007). Finally, abstractions can inform problem conceptualizations capturing a specific complexity regulation challenge currently faced, e.g., feedback delays, change buffering, or highly dispersed feedback. Conceptualizing the complexity challenge can in turn help to allocate resources effectively; it may for example play a role in finding adequate analogies in episodic memory (see next section).

By further implication, system focalizers can supply a basis for problem-oriented reasoning. This can concern root causes and problems lying in the past, as in my previous sketch of Shiatsu reasoning about energy constellations. It can also concern the extrapolation of possible system futures. Experts may develop capacities for simulative mentalization and use these to predict how systemic functions react to particular contingencies (Sterman, 2000). In Shiatsu and Feldenkrais, it is a crucial competency to anticipate the range of possible effects that a specific intervention on a particular system variable can trigger. "Running the system" in the mind for purposes of extrapolation, e.g., helps to pre-empt or counter undesirable side-effects, to take precautionary measures, or to prepare clients for after-treatment effects like tiredness or a brief exacerbation in some cases. Necessarily, many such extrapolations remain of a global kind, yet form a crucial part of an expert's awareness.

TOOLS FOR STRATEGY FINDING

A somewhat different class of concepts assists expert CAS regulators in the function of *strategizing aids*. These have an "if-then" logic and provide some ability to respond to the type of systemic problem context with a coherent regulation strategy, especially when a multi-pronged and holistic approach to DDM seems advisable. The discussed system focalizers provide vital input to

these strategizing aids but can themselves be informed by this reasoning. The two frequently work hand in hand (see Fig. 1).

Instance-Based Reasoning

A number of special strategizing aids have evolved in expert domains to facilitate this. The first important source of global DDM strategizing comes from *instance-based knowledge* (Gonzalez & Dutt, 2011), which uses episodic memories of salient cases and encodes the strategic utility of the approach used. This is well-documented in clinical reasoning research. Inferences may thus proceed as *specific-to-specific reasoning* (Norman & Brooks, 1997; Norman, Young, & Brooks, 2007) to shed light on the present case. In other words, reasoning happens by analogy (cf. Klein, 2003). Suppose an ill-understood problem is at stake, and the expert realizes that the problem is a variant of a familiar issue in different guise. The context is now perceived in terms similar to an already understood context. The precondition for this is to memorize critical incidents that exemplify a problem, e.g., a difficult impasse, an extremely sensitive client, or unusual changes. A global kind of constellational pattern recognition indicates that cases are sufficiently similar. In a Feldenkrais session, a relevant case memory may, e.g., come to be activated by a particular configuration such as a coincidence of slumped shoulders, tilted pelvis and an arching back, or a hypermobile ankle joint and some compensatory muscle strain in the calves. On this basis, a strategy that proved effective in the past can be reviewed and selectively projected onto the case at hand. How nuanced strategies generated from such analogies are, what aspects are selected and mapped to the new context, and how the latter fills in the details remain important questions for future scholarship.

Context and Problem Categories

Experts may explicitly reason on the basis of categories that encode types of contexts and issues in connection with corresponding strategic approaches. Category membership is defined by a set of features. In the bodywork context, a set of perceptual cues (or verbalized complaints) cluster together and are held to be indicators of a particular category, which in turn guides the general type of intervention strategy.

To begin with, bodyworkers frequently report distinguishing general types of systemic problem scenarios, say chronic vs. acute complaints; they also distinguish body or personality types; they know that clients tend to differ in terms of how much structure vs. exploration, monotony, challenge, or repetition they like. They may use physical features or reaction patterns to infer which category the client might fit into. In addition, even quite idiosyncratic situational categories may be applied such as “things to do and to avoid with a client without experience” or “things to watch out for when tired.”

Another type of category used for assessing a client’s constellation concerns types of problems, i.e. ailments and pathologies recognized by the

particular bodywork system. These categories help to coordinate therapeutic reasoning and exploration: Since many perceptual indicators go with different ailments and since first appearances can be ambiguous, therapists often start with a hypothesis based on the first perceptual checks. This hypothesis can then be progressively tested in a process of *abductive reasoning* (Patel & Ramoni, 1997). This means that once several cues of a possible set have been detected, further indicators are strategically checked. Hereby, a hypothesis can be strengthened or rejected and a new hypothesis built. The abductive reasoning process thus combines iterations of targeted exploration with hypothetico-deductive inferences. In other words, the application of categories and interactive explorations mutually enrich each other.

Heuristic Rules

Simple *heuristic rules-of-thumb* (Marewski & Gigerenzer, 2012) are known to inform therapeutic assessment and action strategies. Heuristics are often encapsulated in teacher adages or text-book principles and provide a simple rule for action. A Feldenkrais therapist might, for example, identify body components for intervention following the heuristic notion "address what moves along easiest." So if the aim is to mobilize a rigid ribcage and, during various gentle micro-mobilizations, co-players such as the clavicle are seen responding, the therapist begins by using what the client system offers in terms of degrees of freedom and then tries to progressively implicate further components into the mobilization.

Heuristics can also direct the diagnostic focus of intervention. In Shiatsu an energetically overactive zone usually has a depleted counterpart that should be looked at. The diagnostic heuristic can in turn inform an action heuristic such as "address the most depleted and most hyperactive component of the client." Some heuristic ideas, such as "use developmental knowledge about infants" in working with a Feldenkrais client, can be used to generate context-sensitive strategies. One particular therapist, faced with a client who could not release the arm's weight fully, "thought up" a strategy to relax it by browsing through memories of things that relax babies. Self-touch is one such thing; this idea was easy to implement by softly bringing the back of the hand to the cheek. So effectively, the therapist fleshed out the heuristic by summoning up an ad hoc category "things that relax babies" and used one instance that was easy to implement from the position the client was in.

Computational Models

Finally, reasoning about systemic strategies may also run via specialized computational models, which are dedicated to identifying problem causalities or related tasks. A case in point are the semantic network tools developed by traditional Chinese medicine, such as the *transformation cycles* network, which Kavoussi (2007, p. 295) describes as follows: "The cognitive value of this fully-connected semantic network resides in the fact that with

sufficient training it can facilitate the quasi-mechanical structural recognition, classification and generalization of complex patterns based on the aggregation of variable-weights and relationship-strengths alone." These semantic networks supply a tool to discern root causes or systemic propagation paths of problems. This happens by diagrammatic reasoning: Associated variables shown as connected arrows in a diagram suggest connected causal contributors to a problem. In Shiatsu, transformation cycles and related network tools are used by therapists (Kimmel & Irran, 2021) to feed diagnostic indicators into the semantic network, primarily in constellations when simpler strategic approaches get scarce results, when system appearance is ambiguous or the salient symptoms misleading, or when chronic problems are at issue that would lead to relapse if the systemic intervention is not "deep" enough. Computing deeper systemic causes thus helps to identify the optimal intervention point for system-wide, sustainable intervention. We can speak of a sophisticated, albeit pre-technical reasoning algorithm, the output of which can, in a Shiatsu context, be additionally refined and verified by embodied exploration procedures.

Computational tools need not be implemented in the imagination or in diagrams. They can also be physically implemented in navigation aids, tool panel arrangements, or particular group and teamwork configurations as described by distributed cognition theory (Hutchins, 1995a, 1995b, 2012; Naikar & Elix, 2016). Specialized technical implements, workspaces, and interaction procedures can thus be frequently understood as supplying computational outputs that inform an expert's CAS regulation.

TASK SUPERVISION AND SYNOPSIS

In professional CAS regulation multiple resources and problem spaces need to be held in focus. Handling such a multi-dimensional task ecology poses a substantial challenge, which requires highly organized attentional and memory performance, as well as cognitive integration efforts across many spatial and temporal dimensions.

Situation Awareness

Knowing what to keep into one's attentional focus in order to capture holistically what is going on in a professional setting requires what Endsley (1995) calls *situation awareness* (SA). SA is a cognitive function that integrates relevant aspects into a synoptic model in long-term working memory (Ericsson & Kintsch, 1995), an updatable, and – in many contexts – a repeatedly enriched cognitive structure. Long-term working memory is held to provide a kind of expanded memory system that experts can use to keep track of an extended event and integrate a large amount of information. Experts thus create a multi-faceted *situation model* (Zwaan, 1999), which supports SA by tracking real-time system evolution and assessing where one stands with respect to the task, context, and interaction history, all in light of domain knowledge.

SA is already demanding in non-complex professions. The challenge grows massive in CAS regulation contexts where one must remain aware of

changes in multiple dimensions, monitor system behavior comprehensively, and track delayed effects as well as occurrences remote from "where the action is." In a complex context, SA thus needs to read the state of the system as a network of relations with a particular dynamic evolution and history. And indeed, CAS regulators demonstrably possess global system attention (Fischer & Gonzalez, 2016), track multiple system variables relationally (Dörner, 1997), discern feedback structures of different sub-tasks (Diehl & Sterman, 1995), look for non-salient causal co-variation, and effectively reduce uncertainty through "reflection in action" (van den Heuvel, Alison, & Power, 2014). The cognitive ability to perceive contextual backgrounds may contribute as well (cf. Nisbett, 2003), as SA ties in with abilities for global gestalt perception.

Experienced practitioners of any domain know which things matter for their SA. This can include team communication, information systems and many other aspects, depending on the domain. In Feldenkrais and Shiatsu context, therapists monitor the following dimensions: (a) the status of the interaction with the client, the quality of the encounter and rapport, as well as interventions a client responded to well or disliked; (b) the completeness of diagnosis and the degree of task progress made (e.g., signs of relief in the client); (c) the client's system status, as well as its evolution over time; therapists may frequently compare memorized "snapshots" of the condition at different moments and read this status against the backdrop of prior sessions and reports about injury, medication, diet, lifestyle, and how complaints manifest. Even a situation model of several treatment sessions can be created, which integrates salient memories into a progressively enriched "case-gestalt." Bodywork requires an integral evaluation of all these factors in order to anticipate risks when using potentially harmful techniques or to be aware of imponderables of the situation.

Process Meta-regulation

On the basis of SA, CAS regulators develop process supervision and management capabilities. SA thus feeds into a "meta-regulative stance" (Veenman, Van Hout-Wolters, & Afflerbach, 2006) and informs decisions of "what to do when" in the regulation task (Jansson, 1994). Meta-recognitional processes also ensure optimal resource allocation (Cohen, Freeman, & Wolf, 1996; MacIntyre, Igou, Campbell, Moran, & Matthews, 2014) As Cohen and colleagues (p. 206) put it, these processes "determine when it is worthwhile to think more about a problem; identify evidence-conclusion relationships within a situation model; critique situation models for incompleteness, conflict, and unreliability; and prompt collection or retrieval of new information and revision of assumptions." A meta-regulative stance also provides a basis for self-evaluation and for "monitoring the boundary conditions of the current model for competence (how strategies are matched to demands) and adjusting or expanding that model to better accommodate changing demands" (Woods, 2006, p. 22).

Supervisory and meta-regulative skills are well documented for bodywork (Ajjawi & Higgs, 2012; Higgs & Jones, 2000; Jensen, Gwyer, Shepard, & Hack, 2000; Klemme & Siegmann, 2015) and span the following aspects: (a) Bodyworkers reason about time constraints, e.g., that a problem popping up towards the end of a session is best left alone until the next appointment since the client needs sufficient time to integrate what was already achieved. (b) Bodyworkers determine when emergency measures are needed by keeping track of how typical or anomalous a situation is. This may also involve the assessment of the perceived problem complexity, dynamicity, delays, time pressures, risk of side-effects, or unknowns in the system (cf. Diehl & Sterman, 1995). (c) Bodyworkers supervise their attentional and cognitive load, say when parallel goals are held in focus or when deciding what to prioritize and how long to give each task. (d) Related, bodyworkers may frequently evaluate how effective their current cognitive strategies and tools are in light of the ongoing process, the certainty of the problem assessment, necessity of further tests, or problem granularity. This cognitive self-evaluation notably indicates when to engage in effortful critical thinking, which is especially crucial for anomalous or unexpected situations, where gaps in SA may need to be identified and attention re-allocated. For example, treatment contexts frequently arise where only a sub-set of indicators makes interpretive sense, triggering a focused and deliberative comparison with possible alternative conceptualizations of the constellation. (e) Bodyworkers select their preferred strategic reasoning aids (e.g., pattern recognition, case-based analogy, heuristics and principles, hypothetico-deductive reasoning) to match the task demands. For example, in the context of chronic problems systematic deductive reasoning may be preferred in view of the expectable multi-causality and hidden variables.

This supervisory self-evaluation is crucial to error management, for example to determine whether a bad result was caused by a deficient problem model or gap in SA, by misidentified goals, by overlooked or incorrectly interpreted feedback, or simply by ineffective operational tactics. Also, effective self-evaluation is a highly holistic matter. Time expenditure and cognitive costs may often need to be weighed against possible efficiency gains when determining: “Do heuristics suffice?” “Is case-based analogy fruitful?” “How much problem simplification is admissible?” “Can more complete information gathering afford gains?” “Is trial-and-error sufficient?” “Is an improvised or more structured approach advisable?”

Strategic Routes

I would now like to give readers a sense of the global alternatives in approaching a CAS context, which are informed by system focalizers, strategy aids, and supervisory functions. Our bodywork data suggest that CAS regulators often reason at a relatively abstract level about how to combine local with global, specific with unspecific, and stabilizing with perturbing stimuli, how to weigh open exploration relative to specific focalization, when to give self-

organized change time, when to gently nudge or decisively stimulate the process, how to buffer side-effects, and how to best utilize intrinsic system dynamics.

1. A general question is how "invasive" to be relative to the target system, with respect to the right timing for powerful interventions and for letting endogenous system dynamics run their course. Shiatsu and Feldenkrais prefer a style of regulation that encourages mindful self-awareness in the client and works with intrinsic system dynamics, perturbs only gently, and follows a philosophy of "less is more," with a playful, probing attitude, going with what works easiest, and progressively advancing transformations via multiple parallel routes. Therapists slowly prepare the ground for sustainable change, give clients time to familiarize themselves with new states, and accompany ongoing transformations by "sweetening the pill" via soothing or distracting actions while delivering the challenging stimulus.

2. As to intervention directionalities, effective regulatory leverage on a self-organizing CAS can happen from the bottom-up or from the top-down. A first type of leverage mechanism addresses the target CAS in a non-deterministic or "broadband" fashion to create favorable constraints that enable self-reorganization. Such interventions set control parameters globally. The intervention directionality operates top-down to trigger downward spreading activation to multiple sub-systems, once the CAS is globally "energized." There is some variation as to how deterministic and specific the actions that seek such macro-scopic leverage are. Generic principles, general regulation virtues, and good interfacing skills may sometimes suffice. More specific intervention techniques operate from the top-down as well, including some that follow relatively focalized aims: For example, specific Shiatsu acupoints can globally trigger lung function activation, buffer a circulatory collapse, or even trigger labor in pregnant women. An altogether different type of intervention strategy works bottom-up by serially addressing several elements or relations. The aim is to trigger an overall systemic effect by judiciously combining interventions of local scope. We can think of this as incremental synergy building. A therapist might progressively de-block several joints or imbalanced muscle antagonists to invite a combined effect. This approach may start by manipulating the wrist, then additionally bringing the elbow into play, and finally the shoulder as well within a movement that involves all of these. Top-down and bottom-up approaches are frequently mixed, though. For example, autocatalytic abilities can first be strengthened through a global strategy to prepare for specific interventions once the client is in a "potent state" (Kimmel et al., 2015). The availability of different paths also provide fallback options: For example, muscle tension can be regulated directly through massaging of various affected body parts, but when this gets little results a Shiatsu therapist might activate noradrenalin via an acupoint that is known to trigger the same reaction globally.

3. A somewhat overlapping strategic factor is the question of the primary approach to systemic change as such. The alternatives can be nicely

expressed in terms of how a regulator approaches the behavioral attractors (or repellers for dispreferred patterns) of a CAS. These notions from complexity science (Kelso, 1995) in fact nicely capture distinctions experts themselves would also mention: Firstly, to sensitize a bodywork client, the available behaviors (i.e. the attractor landscape) can be jointly explored with the therapist's assistance. A slow stock-taking can often suffice to trigger a processes of self-reorganization. We may call this a problem-focused approach. Secondly, to counter non-adaptive habitual responses and diversify behavior, therapists may decide to explore present options that remain unnoticed. Often it is sufficient to encourage a behavioral variation that activates a neighboring attractor or advertises a more advantageous patterns. We might say that arising new options "flatten" the dysfunctional troughs of the attractor landscape. Guidance towards new attractors may be termed forward-oriented reorganization (Gelo & Salvatore, 2016) and may, especially when slow and progressive change is the aim, include the building of so-called *latent attractors* that can be activated later in the process (Vallacher, Coleman, Nowak, & Bui-Wrzosinska, 2010). Thirdly, backward-oriented reorganization can be a strategy of choice, which stimulates system memory. A therapist hereby draws attention to attractors that have fallen into disuse, such as when Feldenkrais therapists trigger movement patterns familiar from infancy, an example discussed earlier.

CONCLUSION

It is no understatement that the future of humanity depends on the ability to regulate CAS effectively (Meadows & Wright, 2009). Creating more explicit awareness of competencies for "applied systems thinking" is vital. This presents widespread challenges for scholars, professionals and educators alike; ultimately even the general public who evaluate the performance of experts is an addressee. With this in mind, the present article aimed to take stock of what is needed to perform CAS regulation, using the somatic therapy domains Shiatsu and Feldenkrais bodywork as a naturalistic showcase for expert resources.

Training as a CAS regulator usually begins with a philosophy of practice and complexity-aware thinking habits. The latter sensitize attention (e.g., to dispersed feedback), prepare for a participatory outlook, and create a modest, yet specific identity as facilitator who respects, works with, but also constrains ongoing self-organizing processes of the target CAS. To be of practical value, this mindset needs concretizing into performative DDM competencies, which need to be deployed in a process of recursive assessment and strategizing while the system responds to intervention. A basic prerequisite lies in the ability to interface with the target CAS in effective ways and to use interactivity-based strategies of reasoning. Another prerequisite is the ability to explore and keep in view systemic constellations of component interplay, system dynamics, and global causality. I called these "system focalizers."

Professional experts frequently acquit themselves reasonably well of CAS regulation tasks thanks to their rich knowledge-base: They can draw on a

tremendous range of facts about the nature of the CAS, its appearance, and the make-up of its network. Especially structural-functional knowledge proves powerful, since it specifies components, locations, feedback loops and information pathways, and thereby allows expert CAS regulators to imagine how components enter into interplay, in ideal contexts as well as others. Knowing structures and functions is a condition for exploring the system effectively and for identifying problems. It also enhances attention management, the monitoring of changing states, the extrapolation of possible futures, and reasoning about problem constellations (e.g., as to their root causes). The knowledge base of experts contains a complementary set of "if-then" knowledge which functions as a strategizing aid and helps to determine the global DDM approach for a regulation context. I have illustrated this through inferences by case analogy, scenario types and problem categories, heuristic rules-of-thumb, and computational models.

Finally, supervisory and synoptic aspects were discussed, which ensure integrality of process. In a typical DDM task multi-layered awareness needs to be cultivated "to keep everything together" and this is arguably the most specific hallmark of top-level regulation performance. This involves situation awareness of system status, the interaction quality, and degree of task completion. Situation awareness in turn feeds into meta-regulative processes, which able CAS regulators keep active in the background. These processes have the purpose to reflexively assess how appropriate current strategies or cognitive tools are in view of time, attention, or problem constraints, especially by factoring in these aspects within a summary evaluation.

We can think of the discussed dimensions as a meshwork of cognitive and applied tools. That is, they comprise an integral competency system in which all elements are critical to learn and in which failure of each can be a source of regulation errors. At the same time the elements frequently mesh in a particular task situation. In the unfolding DDM process, the various competencies can, and typically will, scaffold each other over time; they can also synergize when deployed in parallel. The general implication is that future research in professional CAS domains needs to (a) investigate each competency in its own right, and (b) investigate the many possible functional relationships between them as well.

With this framework I hope to advance research in several ways. In terms of applied benefits, it can facilitate self-reflection of learners and experts, create a common meta-language expressing intuitions of practice, and hereby tie subjective meanings to ideas from complexity theory. It can also help to create training materials and experiential contexts (Jacobson, 2000; Jacobson & Wilensky, 2006). In terms of scholarly benefits, the proposed framework places greater emphasis than most previous research on embodied and interactive aspects, while also explaining how domain-specific knowledge guides practice. As such the framework may also help to build bridges between different research traditions. Future research on CAS regulation stands to benefit from

cross-fertilizing complexity theory with ideas about naturalistic expert cognition, the study of DDM dynamics, and the role of embodied cognition that emphasizes the situatedness of applied systems reasoning.

ACKNOWLEDGEMENTS

The empirical data was collected and analyzed in collaboration with the scholar-practitioners Christine Irran (Shiatsu) and Martin Luger (Feldenkrais Method), both of whom I wish to express my profound gratitude towards and both of whom have contributed suggestions. I am also grateful to Hillel Braude for his careful reading of an earlier text version. This article was supported by grants P-23067 and P-33289 of the Austrian Science Fund (FWF).

REFERENCES

Ajjawi, R., & Higgs, J. (2012). Core components of communication of clinical reasoning: A qualitative study with experienced Australian physiotherapists. *Advances in Health Sciences Education, 17*, 107–119. doi: 10.1007/s10459-011-9302-7

Assaraf, O. B.-Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching, 42*, 518–560. doi: 10.1002/tea.20061

Assaraf, O. B.-Z., & Orion, N. (2009). System thinking skills at the elementary school level. *Journal of Research in Science Teaching, 47*, 540-553. doi: 10.1002/tea.20351

Bell, I. R., Koithan, M., & Pincus, D. (2012). Methodological implications of nonlinear dynamical systems models for whole systems of complementary and alternative medicine. *Forschende Komplementärmedizin / Research in Complementary Medicine*, *19*(s1), 15–21. doi: 10.1159/000335183

Brehmer, B. (1992). Dynamic decision making: Human control of complex systems. *Acta Psychologica*, *81*, 211–241. doi: 10.1016/0001-6918(92)90019-A

Brehmer, B. (2005). Micro-worlds and the circular relation between people and their environment. *Theoretical Issues in Ergonomics Science*, *6*, 73–93. doi: 10.1080/14639220512331311580

Brown, A., Karthaus, C. L., & Adams, B. D., (2009). *The role of mental models in dynamic decision making*. Contract report no. CR-2008-060, DRDC Toronto.

Buchanan, P., & Ulrich, B. (2001). The Feldenkrais Method ®: A dynamic approach to changing motor behavior. *Research Quarterly for Exercise and Sport, 72*, 315-323. doi: 10.1080/02701367.2001.10608968

Cavana, R. Y., & Maani, K. E. (2000, August). *A methodological framework for integrating systems thinking and System Dynamics*. Paper presented at the 18th International Conference of the System Dynamics Society: "Sustainability in the Third Millennium," Bergen, Norway.

Cohen, M. S., Freeman, J. T., & Wolf, S. (1996). Metarecognition in time-stressed decision making: Recognizing, critiquing, and correcting. *Human Factors, 38*, 206–219.

Crandall, B., Klein, G., & Hoffman, R. (2006). *Working minds. A practitioner's guide to cognitive task analysis*. Cambridge, MA: MIT Press.

De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making: An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, *6*, 485–507. doi: 10.1007/s11097-007-9076-9

Diehl, E., & Sterman, J. D. (1995). Effects of feedback complexity on dynamic decision making. *Organizational Behavior and Human Decision Processes*, *62*, 198–215.

Dörner, D. (1997). The logic of failure: Recognizing and avoiding error in complex situations. Cambridge, MA: Perseus.

Dörner, D., & Funke, J. (2017). Complex problem solving: What it is and what it is not. *Frontiers in Psychology*, *8*, 1153. doi: 10.3389/fpsyg.2017.01153

Endsley, M. R. (1995). Toward a theory of situation awareness in dynamic systems. *Human Factors*, *37*, 32–64.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychological Review*, *102*, 211–245.

Feltovich, P., Spiro, R. J., & Coulson, R. L. (1997). Issues of expert flexibility in contexts characterized by complexity and change. In P. Feltovich, K. M. Ford, & R. R. Hoffman (Eds.), *Expertise in context* (pp. 125-146). Menlo Park, CA: AAAI, MIT Press.

Fischer, A., Greiff, S., & Funke, J. (2012). The process of solving complex problems. *The Journal of Problem Solving*, *4*(1). 19-42. doi: 10.7771/1932-6246.1118

Fischer, H., & Gonzalez, C. (2016). Making sense of dynamic systems: How our understanding of stocks and flows depends on a global perspective. *Cognitive Science*, *40*, 496–512. doi: 10.1111/cogs.12239

Fogel, A. (2013). Better or worse: A study of day-to-day changes over five months of Rosen method bodywork treatment for chronic low back pain. *International Journal of Therapeutic Massage & Bodywork*, *6*(3), 14. doi: 10.3822/ijtmb.v613.200

Fraser, S. W., & Greenhalgh, T. (2001). *Coping with complexity: Educating for capability*. British Medical Journal, *323*, 5. doi: 10.1007/s11097-012-9254-2

Froese, T., & Fuchs, T. (2012). The extended body: A case study in the neurophenomenology of social interaction. *Phenomenology and the Cognitive Sciences*, *11*, 205–235. doi: 10.1007/s11097-012-9254-2

Funke, J. (2001). Dynamic systems as tools for analysing human judgement. *Thinking & Reasoning*, *7*, 69–89. doi: 10.1080/13546780042000046

Gary, M. S., & Wood, R. E. (2016). Unpacking mental models through laboratory experiments: Unpacking mental models through laboratory experiments. *System Dynamics Review*, *32*(2), 101–129. doi: 10.1002/sdr.1560

Gelo, O. C. G., & Salvatore, S. (2016). A dynamic systems approach to psychotherapy: A meta-theoretical framework for explaining psychotherapy change processes. *Journal of Counseling Psychology*, *63*, 379–395. doi: 10.1037/cou0000150

Godin, P. J., & Buchman, T. G. (1996). Uncoupling of biological oscillators: A complementary hypothesis concerning the pathogenesis of multiple organ dysfunction syndrome. *Critical Care Medicine*, *24*, 1107–1116.

Goldberger, A. L. (2006). Complex systems. *Proceedings of the American Thoracic Society*, *3*, 467–471. doi: 10.1513/pats.200603-028MS

Gonzalez, C., & Dutt, V. (2011). Instance-based learning: Integrating sampling and repeated decisions from experience. *Psychological Review*, *118*, 523–551. doi: 10.1037/a0024558

Gonzalez, C., Fakhari, P., & Busemeyer, J. (2017). Dynamic decision making: Learning processes and new research directions. *Human Factors, 59*, 713–721. doi: 10.1177/0018720817710347

Gonzalez, C., Vanyukov, P., & Martin, M. K. (2005). The use of microworlds to study dynamic decision making. *Computers in Human Behavior*, *21*, 273–286. doi: 10.1016/j.chb.2004.02.014

Greenhalgh, T., & Papoutsi, C. (2018). Studying complexity in health services research: Desperately seeking an overdue paradigm shift. *BMC Medicine*, *16*(95). doi: 10.1186/s12916-018-1089-4

Guastello, S. J. (2002). *Managing emergent phenomena: Nonlinear dynamics in work organizations*. Mahwah, NJ: Erlbaum.

Guastello, S. J. (2014). *Human factors engineering and ergonomics: A systems approach (2nd edition).* Boca Raton, FL: CRC Press.

Guastello, S. J. (2016). A nonlinear paradigm for resilience, workload, performance, and clinical phenomena. *Industrial and Organizational Psychology*, *9*, 509–516. doi: 10.1017/iop.2016.48

Haken, H., & Schiepek, G. (2010). *Synergetik in der Psychologie: Selbstorganisation verstehen und gestalten*. [*Synergetics in psychology: Understanding and shaping self-organization*]. Göttingen, Germany: Hogrefe.

Harrison, S. J., & Stergiou, N. (2015). Complex adaptive behavior and dexterous action. *Nonlinear Dynamics, Psychology, and Life Sciences*, *19*, 345–394.

Higgs, J., & Jones, M. A. (2000). Clinical decision making and multiple problem spaces. In J. Higgs & M. A. Jones (Eds.), *Clinical reasoning in the health professions* (pp. 3–17). Amsterdam, The Netherlands: Elsevier.

Hoc, J. M., & Amalberti, R. (2007). Cognitive control dynamics for reaching a satisficing performance in complex dynamic situations. *Journal of Cognitive Engineering and Decision Making*, *1*, 22–55. doi: 10.1177/155534340700100102

Hotaling, J. M., Fakhari, P., & Busemeyer, J. R. (2015). Dynamic decision making. In S. Smelser & P. B. Batles (Eds.), *International encyclopedia of the social & behavioral sciences* (pp. 708–713). Amsterdam, The Netherlands: Elsevier. doi: 10.1016/B978-0-08-097086-8.43040-0

Hurley, S. (2001). Perception and action: Alternative views. *Synthese*, *129*, 3–40.

Hutchins, E. (1995a). *Cognition in the wild*. Cambridge, MA: MIT Press.

Hutchins, E. (1995b). How a cockpit remembers its speed. *Cognitive Science*, *19*, 265–288.

Hutchins, E. (2012). Concepts in practice as sources of order. *Mind, Culture, and Activity*, *19*, 314–323. doi: 10.1080/10749039.2012.694006

Ingold, T. (2011). *Being alive: Essays on movement, knowledge and description*. London, UK: Routledge.

Jacobson, M. J. (2000). Problem solving about complex systems: Differences between experts and novices. In B. Fishman & S. O'Connor-Divelbiss (Eds.), *Fourth international conference of the learning sciences* (pp. 14–21). Mahwah, NJ: Erlbaum.

Jacobson, M. J., & Wilensky, U. (2006). Complex systems in education: Scientific and educational importance and implications for the learning sciences. *Journal of the Learning Sciences*, *15*, 11–34. doi: 10.1207/s15327809jls1501_4

Jansson, A. (1994). Pathologies in dynamic decision making: Consequences or precursors of failure? *Sprache & Kognition, 13*, 160–173.

Jensen, G. M., Gwyer, J., Shepard, K. F., & Hack, L. M. (2000). Expert practice in physical therapy. *Physical Therapy*, *80*, 28–43.

Kavoussi, B. (2007). Chinese medicine: A cognitive and epistemological review. *Evidence-Based Complementary and Alternative Medicine*, *4*, 293–298. doi: 10.1093/ecam/nem005

Keijzer, F. A. (2003). Self-steered self-organization. In W. Tschacher & J.-P. Dauwalder (Eds.). *The dynamical systems approach to cognition (*pp. 243–259). River Edge, NJ: World Scientific.

Kelso, S. (1995). *Dynamic patterns: The self-organization of brain and behavior*. Cambridge, MA: MIT Press.

Kim, D. H., & Anderson, V. (2007). *Systems archetype basics: From story to structure*. Waltham, MA: Pegasus Communications.

Kim, D.-H. (2000). *Systems archetypes I: Diagnosing systemic issues and designing High-leverage Intervention.* Waltham, MA: Pegasus Communications.

Kimmel, M. (2017). The complexity of skillscapes: Skill sets, synergies, and meta-regulation in joint embodied improvisation. In J. Gore & P. Ward (Eds.), *Proceedings of the 13th international conference on naturalistic decision making, 20-23 June 2017* (pp. 102–109). Bath, UK: University of Bath, School of Management Research Office.

Kimmel, M., Hristova, D., & Kussmaul, K. (2018). Sources of embodied creativity: Interactivity and ideation in contact improvisation. *Behavioral Sciences*, *8*, 52. doi: 10.3390/bs8060052

Kimmel, M., & Irran, C. (2021). Decision-making in Shiatsu bodywork: Complementariness of embodied coupling and conceptual inference. *Phenomenology and the Cognitive Sciences*. In press. doi: 10.1007/ s11097-020-09718-7

Kimmel, M., Irran, C., & Luger, M. (2015). Bodywork as systemic and inter-enactive competence: Participatory process management in Feldenkrais Method® & Zen Shiatsu. *Frontiers in Psychology*, *5*, 1424. doi: 10.3389/fpsyg.2014.01424

Kirsh, D. (2009). Problem solving and situated cognition. In P. Robbins & M. Aydede (Eds.), *The Cambridge handbook of situated cognition* (pp. 264–306). Cambridge, UK: Cambridge University Press.

Kirsh, D. (2014). The importance of chance and interactivity in creativity. *Pragmatics & Cognition*, *22*, 5–26. doi: 10.1075/pc.22.1.01kir

Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. *Cognitive Science*, *18*, 513–549.

Klein, G. (1998). *Sources of power. How people make decisions.* Cambridge, UK: MIT Press.

Klein, G. (2003). *The power of intuition*. New York, NY: Doubleday.

Klein, G., & Hoffman, R. (2008). Macrocognition, mental models, and cognitive task analysis methodology. In J. M. Schraagen, L. Militello, T. Ormerod, & R. Lipshitz (Eds.), *Naturalistic decision making and macrocognition* (pp. 57–80). Farnham, Surry, UK: Ashgate.

Klemme, B., & Siegmann, G. (2015). *Clinical reasoning* (2nd ed.). Stuttgart, Germany: Thieme.

Koithan, M., Bell, I. R., Niemeyer, K., & Pincus, D. (2012). A complex systems science perspective for whole systems of complementary and alternative medicine Research. *Forschende Komplementärmedizin/Research in Complementary Medicine*, *19*(s1), 7–14. doi: 10.1159/000335181

Lane, D. C., & Oliva, R. (1998). The greater whole: Towards a synthesis of system dynamics and soft systems methodology. *European Journal of Operational Research*, *107*, 214–235. doi: 10.1016/S0377-2217(97)00205-1

Latash, M. L. (2008). *Synergy*. Oxford, UK: Oxford University Press.

Levy, S. T. (2017). Learning about complex systems from the bottom up: Role-playing together in a participatory simulation. In I. Levin & D. Tsybulsky (Eds.), *Optimizing STEM education with advanced ICTs and simulations:* (pp. 158–185). Hershey, PA: IGI Global. doi: 10.4018/978-1-5225-2528-8

Levy, S. T., & Wilensky, U. (2008). Inventing a "mid level" to make ends meet: Reasoning between the levels of complexity. *Cognition and Instruction*, *26*, 1–47. doi: 10.1080/07370000701798479

Lipshitz, R., Klein, G., Orasanu, J., & Salas, E. (2001). Taking stock of naturalistic decision making. *Journal of Behavioral Decision Making*, *14*, 331–352. doi: 10.1002/bdm.381

Luger, M. (2014). Der Körper ist System. [The body is a system] *Systemische Notizen*, *2*, 26–35.

Maani, K. E., & Maharaj, V. (2004). Links between systems thinking and complex decision making. *System Dynamics Review*, *20*, 21–48. doi: 10.1002/ sdr.281

MacIntyre, T. E., Igou, E. R., Campbell, M. J., Moran, A. P., & Matthews, J. (2014). Metacognition and action: A new pathway to understanding social and cognitive aspects of expertise in sport. *Frontiers in Psychology*, *5*. doi: 10.3389/fpsyg.2014.01155

Marewski, J. N., & Gigerenzer, G. (2012). Heuristic decision making in medicine. *Dialogues in Clinical Neuroscience*, *14*, 77–89.

Meadows, D. H., & Wright, D. (2009). *Thinking in systems: A primer*. London, UK: Earthscan.

Moore, D. T., & Hoffman, R. R. (2011). Data-frame theory of sensemaking as a best model for intelligence. *American Intelligence Journal*, *29*, 145–158.

Naikar, N., & Elix, B. (2016). Integrated system design: Promoting the capacity of sociotechnical systems for adaptation through extensions of cognitive work analysis. *Frontiers in Psychology*, *7*, 962. doi: 10.3389/fpsyg.2016. 00962

Nguyen, N. C., Graham, D., Ross, H., Maani, K., & Bosch, O. (2012). Educating systems thinking for sustainability: Experience with a developing country: Educating systems thinking for sustainability. *Systems Research and Behavioral Science*, *29*, 14–29. doi: 10.1002/sres.1097

Nisbett, R. (2003). *The geography of thought. How Asians and Westerners think differently ... and why*. New York, NY: Free Press.

Norman, G., & Brooks, L. R. (1997). The non-analytical basis of clinical reasoning. *Advances in Health Science Education*, *2*(2), 173–184.

Norman, G., Young, M., & Brooks, L. (2007). Non-analytical models of clinical reasoning: The role of experience. *Medical Education*, *41*, 1140–1145. doi: 10.1111/j.1365-2923.2007.02914.x

Normann, B. (2020). Facilitation of movement: New perspectives provide expanded insights to guide clinical practice. *Physiotherapy Theory and Practice*, *36*, 769–778. doi: 10.1080/09593985.2018.1493165

Øberg, G. K., Normann, B., & Gallagher, S. (2015). Embodied-enactive clinical reasoning in physical therapy. *Physiotherapy Theory and Practice*, *31*, 244–252. doi: 10.3109/09593985.2014.1002873

Osman, M. (2010). *Controlling uncertainty: Decision making and learning in complex worlds*. Oxford UK: Wiley-Blackwell. doi: 10.1002/9781444328226

Palanjian, K. (2004). Shiatsu. *Seminars in Integrative Medicine*, *2*(3), 107–115. doi: 10.1016/j.sigm.2004.09.001

Patel, V. L., & Ramoni, M. F. (1997). Cognitive models of directional inference in expert medical reasoning. In P. J. Feltovich, K. M. Ford, & R. R. Hoffman (Eds.), *Expertise in context* (pp. 67–99). Menlo Park, CA: AAAI Press.

Pincus, D. (2012). Self-organizing biopsychosocial dynamics and the patient-healer relationship. *Forschende Komplementärmedizin/Research in Complementary Medicine*, *19*(s1), 22–29. doi: 10.1159/000335186

Pincus, D., & Metten, A. (2010). Nonlinear dynamics in biopsychosocial resilience. *Nonlinear Dynamics, Psychology, and Life Sciences, 14*, 353-380.

Raja, V. (2018). A theory of resonance: Towards an ecological cognitive architecture. *Minds and Machines*, *28*(1), 29–51. doi: 10.1007/s11023-017-9431-8

Richardson, G. P., Andersen, D. A., Maxwell, T. A., & Stewart, T. R. (1994). Foundations of mental model research. In *Proceedings of the 1994 international system dynamics conference: Problem Solving Methodologies* (pp. 181–192). Stirling, Scotland: International Systems Dynamics.

Robbins, P., & Aydede, M. (2009). *The Cambridge handbook of situated cognition*. Cambridge, UK: Cambridge University Press.

Röhricht, F. (2009). Body oriented psychotherapy. The state of the art in empirical research and evidence-based practice: A clinical perspective. *Body, Movement and Dance in Psychotherapy*, *4*, 135–156. doi: 10.1080/ 17432970902857263

Ross, S. N., & Ware, K. (2013). Hypothesizing the body's genius to trigger and self-organize its healing: 25 years using a standardized neurophysics therapy. *Frontiers in Physiology*, *4*. doi: 10.3389/fphys.2013.00334

Rywerant, Y., & Feldenkrais, M. (2003). *The Feldenkrais method: Teaching by handling*. New York, NY: Basic Health Publications and K.S. Giniger Co.

Sabelli, H., & Lawandow, A. (2010). Homeobios: The patterns of heartbeats in newborns, adults, and elderly patients. *Nonlinear Dynamics, Psychology, and Life Sciences*, *14*, 381–410.

Sabelli, H., Sugerman, A., Kovacevic, L., Kauffman, L., Carlson-Sabelli, L., Patel, M., & Konecki, J. (2005). Bios Data Analyzer. *Nonlinear Dynamics, Psychology, and Life Sciences*, *9*, 505–538.

Schiepek, G. (1986). *Systemische Diagnostik in der klinischen Psychologie*. [*System diagnosis in clinical psychology*]. Weinheim, Germany: Beltz.

Schiepek, G., Eckert, H., & Kravanja, B. (2013). *Grundlagen Systemischer Therapie und Beratung: Psychotherapie als Förderung von Selbstorganisationsprozessen*. [*Foundations of systemic therapy and counseling: Psychotherapy as fostering of self-organization processes*]. Göttingen, Germany: Hogrefe.

Schiepek, G. K., Tominschek, I., & Heinzel, S. (2014). Self-organization in psychotherapy: Testing the synergetic model of change processes. *Frontiers in Psychology*, *5*, 1089. doi: 10.3389/fpsyg.2014.01089

Schiepek, G., Schöller, H., Roswitha, C., Aichhorn, W., & Lichtwark-Aschoff, A. (2018). *A nonlinear dynamic systems approach to psychological interventions*. In E. S. Kunnen, N. M. P. de Ruiter, B. F. Jeronimus, and M. A. E. van der Gaag (Eds.), *Psychosocial development in adolescence* (pp. 51-68). London, UK: Routledge.

Schön, D. (1991). *The reflective practitioner*. Aldershot, UK: Ashgate Publishing Ltd.

Schoppek, W. (2002). Examples, rules, and strategies in the control of dynamic systems. *Cognitive Science Quarterly*, *2*, 63–92.

Seligman, S. (2005). Dynamic systems theories as a metaframework for psychoanalysis. *Psychoanalytic Dialogues*, *15*, 285–319. doi: 10.1080/10481881509348832

Shanteau, J. (2015). Why task domains (still) matter for understanding expertise. *Journal of Applied Research in Memory and Cognition*, *4*(3), 169–175. doi: 10.1016/j.jarmac.2015.07.003

Steffensen, S. V. (2013). Human interactivity: Problem-solving, solution-probing and verbal patterns in the wild. In S. J. Cowley & F. Vallée-Tourangeau (Eds.), *Cognition beyond the brain* (pp. 195–221). London, UK: Springer. http://link.springer.com/10.1007/978-1-4471-5125-8_11

Steffensen, S. V., Vallée-Tourangeau, F., & Vallée-Tourangeau, G. (2016). Cognitive events in a problem-solving task: A qualitative method for investigating interactivity in the 17 Animals problem. *Journal of Cognitive Psychology*, *28*, 79–105. doi: 10.1080/20445911.2015.1095193

Sterman, J. D. (2000). *Systems thinking and modeling for a complex world*. Boston, MA: Irwin/McGraw-Hill.

Strijbos, S. (2010). Systems thinking. In R. Frodeman, K. J. Thompson, & C. Mitcham (Eds.), *The Oxford handbook of interdisciplinarity* (pp. 453–447). Oxford University Press: Oxford University Press.

Strunk, G., & Schiepek, G. (2014). *Therapeutisches Chaos*. [*Therapeutic chaos*] Göttingen, Germany: Hogrefe.

Sweeney, L. B., & Sterman, J. D. (2000). Bathtub dynamics: Initial results of a systems thinking inventory. *System Dynamics Review*, *16*, 249–286. doi: 10.1002/sdr.198

Tschacher, W. (1997). *Prozessgestalten*. [Process gestalts]. Göttingen, Germany: Hogrefe.

Tschacher, W., Dauwalder, J.-P., & Haken, H. (2003). Self-organizing systems show apparent intentionality. In W. Tschacher & J.-P. Dauwalder (Eds.). *The dynamical systems approach to cognition* (pp. 183–200). Singapore: *World Scientific*.

Tschacher, W., & Grawe, K. (1996). Selbstorganisation in Therapieprozessen. Die Hypothese und empirische Prüfung der "Reduktion von Freiheitsgraden" bei der Entstehung von Therapiesystemen. [Self-organization in therapy processes. The hypothesis and empirical verification of 'reduction of degrees of freedom' in the genesis of therapy systems]. *Zeitschrift Für Klinische Psychologie*, *25*, 55–60.

Vallacher, R. R., Coleman, P. T., Nowak, A., & Bui-Wrzosinska, L. (2010). Rethinking intractable conflict: The perspective of dynamical systems. *American Psychologist*, *65*, 262–278. doi: 10.1037/a0019290

van den Heuvel, C., Alison, L., & Power, N. (2014). Coping with uncertainty: Police strategies for resilient decision-making and action implementation. *Cognition, Technology & Work*, *16*, 25–45. doi: 10.1007/s10111-012-0241-8

Vargas, B., Cuesta-Frau, D., Ruiz-Esteban, R., Cirugeda, E., & Varela, M. (2015). What can biosignal entropy tell us about health and disease? Applications in some clinical fields. *Nonlinear Dynamics, Psychology, and Life Sciences*, *19*, 419–436.

Veenman, M. V. J., Van Hout-Wolters, B. H. A. M., & Afflerbach, P. (2006). Metacognition and learning: Conceptual and methodological considerations. *Metacognition and Learning, 1*, 3–14. doi: 10.1007/s11409-006-6893-0

Vester, F. (2007). *Die Kunst vernetzt zu denken*. [*The art of network thinking*]. Munich, Germany: Deutscher Taschenbuch Verlag.

Wallden, M. (2012). Pattern recognition: The miracle of foresight, with the benefit of hindsight. *Journal of Bodywork and Movement Therapies*, *16*, 533–539. doi: 10.1016/j.jbmt.2012.07.010

Weiss, J. N., Qu, Z., & Garfinkel, A. (2003). Understanding biological complexity: Lessons from the past. *The FASEB Journal*, *17*(1), 1–6. doi: 10.1096/fj.02-0408rev

Woods, D. D. (2006). Essential characteristics of resilience. In E. Hollnagel, D. D. Woods, & N. Leveson (Eds.), *Resilience engineering: Concepts and precepts* (pp. 21–34). Abingdon, UK: CRC Press.

Zwaan, R. A. (1999). Embodied cognition, perceptual simulation, and situation models. *Discourse Processes*, *28*, 81–88.