Beyond Distributed Representation: Embodied Cognition Design Supporting Socio-Sensorimotor Couplings

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ABSTRACT
Embodied Cognition has been proposed as a relevant theory for tangible and embedded interaction [14]. Based on two 2-year lasting Research-through-Design cases we identify three variations of the theory: 1) Distributed Representation and Computation, 2) Socially Situated Practices and 3) Sensorimotor Coupling & Enactment. Both social situatedness and sensorimotor coupling proved relevant for design and for understanding user behavior in context. We show how the ‘social’ and the ‘sensorimotor’ are part of one integrated sensemaking process we call ‘socio-sensorimotor coupling’. We argue that the, intuitively appealing, idea of using tangibles for external representation actually hinders designing for sensemaking as socio-sensorimotor coupling. We present a vision of Embodied Cognition Design, which goes beyond a representational interpretation, aiming to intervene more directly into the socio-sensorimotor loop.

Author Keywords
Embodied Cognition, situatedness, practice, sensorimotor coupling, interaction, design, theory, tangible, augmented

ACM Classification Keywords
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General Terms
Design; Theory; Human Factors.

INTRODUCTION
“To understand is to experience the harmony between what we aim at and what is given, between the intention and the performance – and the body is our anchorage in a world”
Merleau-Ponty [23]

Embodied Cognition (EC) is a theory of how people think, act and in general make sense of the world [2]. With the rise of such new fields as augmented reality, ubiquitous computing, tangible interaction, context-aware and wearable computing, we are witnessing an unprecedented trend towards integrating physical form and digital process. The challenges designers are faced with are actually closely related to the theoretical issues in EC [15, 9]. EC has therefore been presented as a relevant set of principles that may inspire interaction design [9, 15, 11, 22].

EC draws from a diversity of areas, ranging from robotics [6] to anthropology [13]. It is therefore not surprising that there are considerable differences, and even conflicting claims, in how the main ideas are elaborated. As we aim to show in this paper, these differences have consequences for design, which show up concretely in how and what to design, as well as in how to make sense of data from user-studies. In what follows, we use lessons learned from two long-term Research-through-Design cases that formed part of a Phd project [33], in order to answer the following question: What does it mean to design from an EC perspective? That is, what can EC bring to design?

PAPER OUTLINE
In what follows, we first introduce EC theory and three variations of it we discovered to be distinctive as well as relevant for our design projects. Next, we introduce the design cases. We discuss the theory by reflecting on concrete design problems and user observations in our cases. We show why one of the variations, the ‘representational’ view, proved to be problematic. We explain how the two other variations, one focused on ‘social interaction’ and the other on ‘sensorimotor coupling’, can be combined, through design, in one integrated perspective. This, then, forms the basis of our vision of Embodied Cognition Design, and we provide directions for such a design in the final part of the paper. But first, the theory.

EMBODIED COGNITION: IN THEORY AND IN DESIGN
EC developed as a rejection of the cognitivist picture of the mind as a information-processing machine (the brain) performing computations (reasonings) on internal representations of the outside world [2, 3]. EC rejects the modularity and sequentiality in classical models, in which cognition is assumed to start first with ‘sensory input’, to be processed internally in distinct mental modules, to result
finally in an appropriate ‘motor output’ [2]. Instead, EC takes the body-in-action as a starting point, being neither ‘inner’ nor ‘outer’, but somewhere in between. Phenomenologist Merleau-Ponty describes the peculiar status of the body as follows:

“I move external objects with the aid of my body, which takes hold of them in one place and shifts them to another. But my body itself I move directly, I do not find it at one point of objective space and transfer it to another, I have no need to look for it, it is already with me ... The relationships between my decision and my body are, in movement, magic ones.” [23, pp. 107-108]

With the body as a grounding structure, EC portrays cognition essentially as a coordination, achieved through a self-organizing network of elements [5]. This network reaches beyond the brain to include bodily constraints, homeostatic levels, sensorimotor properties, as well as dynamic relations between body and the physical- and social environment [2, 12, 17]. In all, body, brain and the environment are seen as part of the cognitive system - part of what makes cognition happen (See figure 1).

**Figure 1:** Sketch of the Embodied Cognition perspective. Cognition emerges from interactions between brain, body and the physical- and social environment © Jelle van Dijk

**EMBODIED COGNITION: THREE FLAVORS**

In this section we distinguish between three ‘flavors’ of EC theory, reviewing literature for each. After that, we introduce the design cases that grounded this tripartition. Even though a large proportion of EC theory is incorporated, parts of it are neglected, as the analysis evolved in service of the actual design cases and their practical demands. Hence, Lakoff and Johnson’s theory of Embodied Metaphor is left aside (see [4]). However, metaphorical designs such as in [4] can be seen as part of Distributed Representation and Computation (explained below). Activity Theory [20], although anti-Cartesian, lies equally beyond the scope of this paper.

**Distributed representation and computation (DRC)**

Seeds of EC can be found in the work of Norman’s ‘knowledge in the world’ [24]. Norman focuses on external representation. For example, he describes his habit of putting his bag against the front door in order not to forget to take the bag to work [24]. Philosopher Andy Clark dubbed this the ‘007 principle’: the environment provides one with information on a ‘need-to-know basis’ [2, p. 46].

In distributed cognition [17] both representing information and processing it (computation), is distributed between brain and the environment. Hutchins shows how intelligent behavior on board of a ship is a cooperative achievement of a system, consisting of brains of people, as well as the physical tools used [17]. This means people not only represent information externally, but also use the environment more actively to reason with. In this regard, David Kirsh explains how pragmatic actions directly contribute to achieving a goal, while epistemic actions reorganize the environment to reduce cognitive load [21]. Taking out a pen and paper would be an epistemic action that makes a hard calculation less difficult, enabling one to solve the problem on paper instead of in the head. Clark calls such tools and props ‘cognitive scaffolds’. Manipulation of physical objects provides cues that enable us to solve problems easily; problems that would be more difficult when using only brain-internal computation [2].

Finally, people tend to live in pre-structured ‘life-worlds’ [1] within which task-related actions consume less cognitive processing than would be expected in isolation. For example, tasks often have a dedicated physical location (cooking is done in a kitchen), tools needed are found close together at the task location, routine maintenance in the background helps to do tasks more easily, and so on [1].

**Figure 2. The Distributed Representation and Computation perspective (DRC). Details in text. © Jelle van Dijk**

A sketch of DRC is given in figure 2. Cognition is a computational-representational process, extending out into the world to include objects and other people for external representation and computation, reducing cognitive load.

**Design from a DRC perspective**

Many tangible interaction designs support exactly the scaffolding strategies as described in the DRC framework. Consider Ullmer & Ishii’s classic paper on the tangible interface [19]. The tangibles PassiveLENS and activeLENS...
each create an interface between the physical body and, in this case, a digital street-plan (figure 3). DRC theory can explain how this reduces cognitive load. ‘Picoms’ (physical icons) are expected to outrank graphical icons, since they exploit people’s natural bodily skills:

Figure 3. Tangible interaction in passiveLENS (left) and activeLENS (right) (Brygg Ullmer, with kind permission)

“Tangible User Interfaces (TUls) are built upon [human sensing and manipulation] skills, and situate … digital information in physical space. The key idea of TUls is to give physical forms to digital information. The physical forms serve as both representations and controls for their digital counterparts.” [18, p.x, my emphasis]

Indeed tangible interfaces like these may provide provide user-friendly interfaces to digital information. This is one way to see EC theory as supporting interaction design.

SOCially Situated PractIce (SSP)
Research originating in anthropology and social science [27, 9] has investigated the way tools become incorporated in socially situated practices. SSP stresses the value of concrete circumstances and opportunities that may arise ‘in action’ [27, 9, 13]. For example, Lucy Suchman [27] argues that people do not first internally create a ‘plan for action’ that is then executed. Instead, a person is found already acting in the face of concrete circumstances in the world. In doing so, plans evolve in an improvised manner. Along the way people adapt, re-organize and use external artifacts:

“…cognitive phenomena have an essential relationship to a publicly available, collaboratively organised world of artefacts and actions, and the significance of artefacts and actions, and the methods by which their significance is conveyed, have an essential relationship to their particular, concrete circumstances.” [27, p. 50]

Importantly, where DRC treats people and physical objects essentially alike, as computational units in a distributed information-processing system [17], SSP shows how objects ‘get taken up’ in a social activity:

“…the real cornerstone of knowledge is people. ... [A] distinction [needs to be made]... between the idea that knowledge can be represented and stored and the view that it has to be contextualized and made relevant to the settings in which it has to be applied. Meaning is not inherent to information; information is made meaningful.” [9, p.185]

For SSP, ‘cognitive scaffolds’ can only exist in the context of a social setting. Without social interrelations, roles, norms, culture, politics, there would be no meaning at all in using artifacts [27, see especially. p 277].

For DRC, physical media are locally available media for storing knowledge ‘in the world’. SSP instead emphasizes how such artifacts (for example, cardboard ‘flight-strips’, used by air-traffic controllers) function as active components in the way work gets organized. ‘What it takes to be a representation is to be used as a representation in the course of some activity...in systems of practice’ [9, p. 208]. In this regard, the public availability of artifacts makes them ‘accountable’, that is, ‘observable and reportable’ by other members of the community of practice [9].

A sketch of SSP is given in figure 4: Cognition is seen as an ongoing achievement of social coordination. Physical artifacts function as mediating objects in the way people deal with each other in the context of a situated practice.

Figure 4: The Socially Situated Practice perspective (SSP). Details in text. © Jelle van Dijk

Design from an SSP perspective
SSP turns the design question on its head: instead of designing how a user can access the digital world, it is the computer that needs to connect to people’s existing embodied practices somehow. As Klemmer et al [22] state:

“Clearly, the digital world can provide advantages. To temper that, we argue that because there is so much benefit in the physical world, we should take great care before unreflectively replacing it. ... solutions that carefully integrate the physical and digital worlds — leaving the physical world alone to the extent possible — are likely to be more successful by admitting the improvisations of practice that the physical world offers.” [22, p. 147.]

Likewise, Ferneaues et al [11] argue that interaction with physical objects directs action to the social setting, and has meaning in and of itself, apart from potential mappings to digital states [11, p. 228].

Consider, as an example, the Reactable, a tangible-mounted interactive surface for creating electronic music (figure 5). Reactable was not designed in explicit reference to SSP, but we can see many of its elements resurfacing. Yes, one could also describe Reactable in terms of DRC. Each ‘tangible’ maps to a particular digital sound (representation) or
manipulation (computation). Yet, SSP helps to show how Reactable is much more than just interfacing this mapping.

That is, using Reactable is a skill, including social interactions, and the shared performance is coordinated by drawing on the public visibility of each musician’s actions. Recently a study provided empirical support for the idea that people indeed create meaning collaboratively using Reactable as a shared space for sensemaking [35].

SENSORIMOTOR COUPLING & ENACTMENT (SCE)

The skills mentioned in the Reactable example hinted at a third strand of research in EC, focusing on sensorimotor activity. The Sensorimotor Coupling & Enactment perspective (SCE) originated in ‘behavior-based’ robotics [5, 6]. These robots drive on sensorimotor couplings in direct interaction with the environment. Instead of internally representing and planning action, such robots navigate ‘us[ing] the world as its own model’, to quote Rodney Brooks [6]. To explain SCE, Clark [2] gives a nice example of a baseball outfielder. Instead of calculating first the goal position and running speed to catch the ball, an outfielder simply starts running, meanwhile making sure that the ball maintains a straight horizontal line in his visual field. By continual adjustments of running speed in order to maintain that straight line, the outfielder is guaranteed to be right at the spot where and when to catch the ball [2].

We can use SCE to understand the notion of affordance [12]. An affordance is the way the world shows up for a perceiver as directly affording some action, based on the sensorimotor coupling in place. So, for instance, a river might show up as ‘crossable’ or ‘non-crossable’ depending whether one running or standing still in front of it. How one sees the world depends on how one is acting in it, while action and perception get coupled over time as coordinations [2, 3]. As part of SCE, an affordance is certainly not a message, encoded in physical form in the object, communicating ‘how it should be used’ [3].

Unfortunately, this is how Don Norman introduced affordances to the HCI community, thereby implicitly subsuming the concept under a DRC perspective [24].

Related to affordances is Varela’s notion of enactment [32]. To ‘enact’ a world means to create meaning through the process of sensorimotor coupling [34, 28]. In a way, the word sense-making should be taken literally:

‘[We see] cognition as the creation and appreciation of meaning or sense-making in short … [M]eaning is in the engagements in which an organism builds its world.” [7, p. 358].

Theories of enactment draw from the philosophical position of phenomenology, which recently gained renewed interest in interaction design [9, 14, 23, 25, 27, 34].

A sketch of SCE is given in figure 6. Cognition is seen as a temporal coupling between action and perception, sustained through continuous bodily interactions with the environment. Through this process meaning is enacted.

Figure 6. The Sensorimotor Coupling & Enactment perspective (SCE). Details in text. © Jelle van Dijk

DESIGN BASED ON THE SCE PERSPECTIVE

Industrial designers have explored a vision called rich- or embodied interaction [8], closely related to sensorimotor theory, emphasizing how meaning is not predefined, but arises in the interaction between user and product [8]. As an example, we consider Stienstra et al’s digitally augmented speed-skate [26], which continuously maps skate-action to acoustic feedback over headphones:

“The amount of pressure delivered is sonified through the intensity and loudness of the band-pass filter; …from the absence of sound while lacking pressure to the intense loudness … while put on full pressure. … Balancing on the backside … translates in a low sound while balancing on the front … translates in a high sound” [26]

In this concept, digital information is not ‘accessed’ through embodied interaction, but instead digital information is fused back into embodied interaction with the world, supporting sensorimotor coupling. This feedback loop need not contain predefined meaning. Feedback will over time come to be recruited for, in this case, skating, and so come to ‘make sense’ for the skater. Meaning is created in the interaction [8]. Or: the skater enacts meaning [34], even if he may not even be able to describe explicitly how.

It is time to take stock. We have discussed EC as consisting of three variations, which is in fact how the theory showed up in our design cases. Let us now present the cases themselves and further discuss the theory in light of these.
THE DESIGN CASES
The analysis in this paper is based on two 2-year lasting Research-through-Design cases [33]. Both consisted of three iterations resulting in working prototypes, including various user-studies with prototypes, co-design sessions, interviews and observations at stakeholder sites. In this section we briefly introduce the cases. Details of these cases and the user studies are reported elsewhere [29, 30, 31, 32].

NOOT, FLOOR-IT and creative group meetings
The systems NOOT and FLOOR-IT were designed to support so-called ‘creative group meetings’. The idea was to build further on the way brainstorm participants readily use physical objects and spatial organizations as tangible aids to gradually develop better, shared understanding of the task at hand. That is, using sticky-notes, whiteboard, physical props and the like, participants not only form ideas; they also develop a better understanding on what the actual challenge is that should be addressed. Our design question was how to support this sensemaking process using interactive technology. The underlying research question was how to apply EC theory to such a challenge. NOOT (figure 7), in its final form, supports shared reflection [29]. It enables people to catch a fleeting moment of ‘reflection’ by using a tangible clip to create a time-mark in an audio-recording of the session. Participants may revisit these earlier moments using a playback device. This way, earlier moments can be elaborated and shared later on.

FLOOR-IT (figure 8) allows people to build a personal ‘trace of thought’ by taking picture-snapshots of meaningful physical elements in the space (e.g. a sticky-note, sketch or mock-up). These personal traces are projected around the body and thereby form a publicly addressable ‘context’ that participants may use to build a shared insight together [30].

CONSTRUCTING THEORY: REFLECTING ON PRACTICE
We now discuss how the three variations of EC emerged from the design projects, and how we ended up going beyond DRC, favoring a combination of SSP and SCE. We present only a selection of design insights, illustrating how the theoretical analysis was shaped by the practice.

DRC, SSP or SCE?
At the start, we implicitly worked mostly from a DRC perspective, thinking about a kind of external, situated storage medium for brainstorm insights. As the projects evolved, the social setting as described in SSP became more significant than the goal of ‘information storage’: when we observed the practice in situ, we could not ignore the fact that whatever was going on, it was in any case a thoroughly a social affair, with people relating to other people in everything they did. At the same time, as designers, we needed direction at the concrete level of embodied interaction. We needed to design for movement, temporal dynamics, bodily position, physical form, and the interactive behavior of the system.

Figure 7. NOOT. Physical tags wth RFID connect to time-points in continuous audio-recording. Tags can be placed iin a relevant spatial setting, e.g. on a sticky-note or on the whiteboard. Using a playback device one may revisit earlier moments in the conversation. © Jelle van Dijk

Figure 8. Floor-It. Self-snapped pictures during the brainstorm are projected around participants as a ‘traces of ones thoughts’ Traces move along with the body and manipulated by foot gestures. They can be used to connect to other people, supporting the formation of shared insight

Here, SCE proved particularly meaningful. In observing people using our prototypes, we saw how they develop and maintain sensorimotor couplings that emerge in ongoing interaction. We realized our tools must connect to this coupling process.

Designing ‘beyond’ DRC
We give three examples showing how we gradually moved away from DRC. We started the NOOT project aiming to design an interactive ‘cognitive scaffold’ [2, 21]. For example, we thought about ‘digitalizing’ sticky-notes, presented on an interactive wall. Later, we saw that participants talk a lot during a brainstorm, but write down only little of it [29]. What added value would be created by digitalizing these ‘poor’ representations? We realized sticky-notes already work more as ‘triggers’ in the conversation itself, than as storage containers of the ‘output’. This insight lead to NOOT: A tool to record the
conversation and provide actionable entry-points for revisiting the conversational history [29].

Later on, we discussed how long an audio-sample for any NOOT-tangible should be. Surely we did not want to miss out on the crucial bit of talk! However, this meant the system had to ‘know’ when to start and stop recording at ‘just the right moments’. Not wanting to invoke futuristic AI technologies, we abandoned recording ‘samples’ altogether and connected each NOOT-tangible to a time-point in the entire recording. A scrolling function invites exploration of the entire session from each tangible starting point. This decision rejected the idea of NOOT-objects as ‘tangible information carriers’; rather, the total set in its spatial organization offers a tangible mapping between the action-space and the conversation history [29].

In the co-design activities leading to FLOOR-IT, we observed how people would talk about sticky-notes and flip-charts as if these were ‘the ideas and insights’, and we saw people transporting paper between sub-sessions, and taking materials home at the end of the day. At the same time, these artifacts hardly represented the actual insights gained in the session, and moreover, people were aware of this. They stated they would ‘probably never look at the materials again’, and they indicated it would be hard to ‘remember what it all meant’, later. As said, these artifacts are useful mostly within a session, as mediating objects through which people negotiate a shared understanding ‘in situ’. We decided to enhance the space to that effect, instead of trying to create better storage devices [30, 31].

In sum, DRC-style thinking lead to problems (Why digitalize sticky-notes? How to catch the right content in the sample? Why save the ‘results’ if nobody will use them?). The solution was to move away from DRC, towards supporting social- and sensorimotor coupling.

Integrating the social- and the sensorimotor perspective
Qualitative observations of a facilitator using NOOT over seven sessions, revealed that the value of NOOT lies in how the act of grabbing and using a NOOT, is a sensorimotor routine. This routine makes a person more sensitive to a reflective mode of perceiving the ongoing activity. Furthermore, the public visibility of using a NOOT may invite other people to respond with reflection as well [31].

In FLOOR-IT, people’s ‘traces of thought’ are taken up as mediating objects in interactions with other people. As a whole, this set-up helps people to get a grip on the challenge, using the floor as a ‘shared action space’ [13]. In a user study (20 brainstorm triads in 20 min. videotaped brainstorm) we compared a working prototype of FLOOR-IT with a control version where images were projected on a wall [32]. Qualitative analysis revealed that traces are used by people to position themselves in relation to others [32]. Social positioning formed crucial for the way the group developed shared insight. When people’s pictures were projected on the wall, this induced problems: it was difficult for people to take up a position vis-à-vis one another as the wall distracted attention from social interaction (Figure 9, left). In FLOOR-IT, as traces were connected to people’s bodies, participants would connect to each other fluidly, using the traces as scaffolding elements for doing so (Figure 9, right). In sum: how users are able to ‘couple’ to their traces in the activity itself may either dissociate social interaction from the interaction with technology, or help to integrate the social and technology interaction into a unified, coherent activity.

In summary, both NOOT and FLOOR-IT illustrate how social interactions in a group are sustained by sensorimotor couplings, and how this ‘in situ’ activity underlies how people make sense collaboratively. This leads us to view cognition as essentially a process of socio-sensorimotor coupling [32]. The cases also provide a first indication of how an Embodied Cognition Design can create technological support for socio-sensorimotor coupling [33].

EMBODIED COGNITION DESIGN: DIRECTIONS
If digital technology is no longer an external memory or computational aid in a distributed cognition, we must rethink the relation between digital process and the embodied setting in which it is embedded. In tangible interaction, physical form is often linked to digital process by pre-determined, metaphorical mappings [18, 4]. In this DRC-style design, bodily interaction is used as a means to present or manipulate something in the digital realm. Metaphorical mappings tend to ignore SSP and SCE’s insistence on the fact that meaning is created ‘in situ’, through situated social positioning and sensorimotor coupling. That is, meanings are not predefined by the mapping relation the designer chooses[9]. The challenge, then, is to couple interactive technology directly to this socio-sensorimotor loop itself.

Based on the analysis so far, we see four ‘entry-points’ that may help designers do just this (See Figure 10):

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[1] More fundamentally, it begs the question of where the meaning of the digital object (that the tangible represents) itself comes from, as it is already presupposed [3].
Figure 10. Four entry-points for designing in support of EC by intervening in the sensing-acting, socially relating or tracing aspect of the complete socio-sensorimotor loop. Details in text.

1. SENSE-TO-ACT transforms or creates new opportunities for the way a person can sense the environment. This means creating new, artificial ‘sensors’, allowing a person to respond to aspects of the environment that they hitherto couldn’t.

2. ACT-TO-SENSE creates new opportunities for physically manipulating the environment. This is not unlike what conventional tools do (with the hammer [14] and the blind-man’s cane [23] as classic examples). Both new ‘sensing possibilities’ or new ‘action-possibilities’ change the complete loop: New sensing ways afford new actions, and new action possibilities create new sensations. In fact all of the four entry-points are just that: they are entry-points to what is ultimately one integrated coupling loop.

3. RELATE provides for new ways of social coordination with other people in face-to-face contact to build and sustains relations with others as part of the sensemaking process. Relevant research has been done on the role of digital technology in mediating social interaction [9]. We suggest to take those insights and situate them in actual, embodied space. This means less of a focus on language and ‘message passing’ over a communication channel, and renewed interest in nonverbal communication and social coordination in action [13].

4. TRACE: Through action, people leave traces in the environment, which subsequently may guide further actions. As both NOOT and FLOOR-IT show, interactive technology can provide for new kinds of traces in the environment that people may then subsequently take up as scaffolds in further activities [30]. The focus here is less on the representational content of such traces (if there is any at all) rather than on the way such traces get taken up into a the socio-sensorimotor loop, that is, how these physical aspects of the environment help coordinating activities of the people in the situation.

TECHNOLOGY AS MATERIAL

In general, we propose to see sensors, actuators and digital processes as ‘material’ to work with, together with physical material [22, 11]. The question is what ‘digital materials’ can offer within the whole of digital- and mechanical form. One opportunity may be that digital process can bring into view as one a collection of temporally or spatially disparate events that, based on our biological body and physical tools, would never become one unified experience. That is, digital technology can put things together that are normally unconnected, allowing the socio-sensorimotor loop to couple to it as a whole. For example, NOOT presents ‘moments in conversation history’ as one spatial configuration, that people may then perceive and react to.

CONCLUSION

Many designs assume cognition to be essentially a computational-representational process, even if one allows the possibility that this process is distributed over brain and environment, as in DRC. DRC aligns intuitively with the vocabulary used to describe computational technology: computers are computational-representational systems par excellence, and it is tempting to describe user practices in these same terms. We do not claim that this is wrong. Good products have been designed based on DRC. Our point is that there seems to be a bias towards DRC in tangible interaction design, perhaps because we are working with digital ‘materials’. Yet, assuming the framework of EC, there is much more to human embodiment than external representation. Moreover, DRC tends to obscure or neglect these two other strands of EC theory: the social- and sensorimotor perspective. Designing explicitly for socio-sensorimotor couplings, we argue, brings new design opportunities and new ways of understanding user behavior.

The body-in-action is a central part of human sensemaking practices, even if, in our digital age, we may sometimes come to forget this. It is uncovered in musical performance, sports, dance, craftsmanship, professional know-how, and in the way we cope with everyday affairs [10]. It is all the more exciting, then, to find that in interactive systems design, using (partly) digital systems, we see a renewed ‘anti-Cartesian’ trend, reconnecting present-day technology to our embodied way of being-in-the-world [8, 9, 16, 22, 25]. With our practice-based analysis of EC theory we hope to have provided some further directions towards this end.

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