8 Eventually Everything Connects

Introduction

What is implicit in this chapter's title (taken from the quotation under figure 8.1[1]) is that there is great deal of trial and error in the continual engagement between designers and their materials before "eventually everything connects" and a design classic such as the Eames chair (figure 8.1)[2] is produced. The notion of continual engagement is at the heart of this book and underpins the concept of radical embodied cognitive science (RECS) it uses. By way of summary, I claim that it is important to adopt a systems view of interactions between human, artifact, and environment. This means that focusing exclusively on any one component or pairing will miss the subtleties and complexities of these interactions. It also means that claims about artifacts becoming "part" of the person (or incorporated into their "body-schema") miss the point. Within the human-artifact-environment system the boundaries between components remain demarcated, but the borders that allow exchange of information and action are permeable, and this is what gives rise to synergies and interactions. Before proceeding, I want to point out that there is little in the discussion so far that requires us to focus exclusively on "digital technology." All of the points that I have been making can apply equally to tools or to everyday artifacts such as kettles, jugs, and cups. When we pick up and use a physical artifact, we are part of a human-artifact-environment system. The artifact participates in interaction not only between it and the human, but also between it and the environment, and also mediates the interaction between human and environment. During activity, this mediated relationship provides information-in-context (in the form of feedback through various sensory channels) that

Figure 8.1
Eames Chair. Charles and Ray Eames were "able to make plywood bend to their will and yield the iconic Eames chair. Not in one week however. From alpha to omega, this project took years to culminate in the final chair. Countless sketches, revisions, practical tests were stepping-stones the Eames took in the process of their designing. Eventually everything connects."

can be used to regulate movement, maintain balance, correct for errors or deviations, and so on.

Creativity and Design

For Glaveanu, one of the most prescient writers on creativity in the 2000s, "Creative action is distributed between multiple actors, creations, places and times."[3] This idea implies the sort of "system" considered in this book and echoes an emphasis on the "organism-in-its-environment."[4] In terms of the human-artifact-environment system, much of the laboratory-based study of creativity has focused on the "human" and has had little concern for the interactions between human and artifacts (or the roles that environmental, physical, and social factors play). However, a review of problem-solving demonstrates how important it can be to allow the person to physically manipulate objects (and that the visual presentation of the problem can influence the choice of strategy to apply). The environment (for the artist, designer, or other creative practitioner) consists of the materials to be worked in order to produce the outcome and some cultural appreciation of what constitutes an acceptable outcome. From these, the creative practitioner works within constraints imposed by the nature of the materials, the types of tool being used, their experience and expertise in working with these, the design brief, and aesthetic, historical and cultural traditions and conventions. The creative practitioner will not satisfy all of these constraints but will work within the problem space defined in terms of one or two constraints. More broadly, one could see the "conversation" between design and these constraints as the ongoing (re)definition of objectives (both in terms of how these are evaluated but also in terms of which objectives to work with). None of the preceding discussion would come as a surprise to the creative practitioner, but I believe that very little of this fits an information-processing approach.

From a degrees-of-freedom perspective, the essential features of creativity are that there are some constraints that are fixed and a few that are open to adaptation by the practitioner. This suggests that some manipulations (of tools and materials) would be more likely to contribute to the outcome than others, either because the nature of the materials constrain some manipulations or because the outcome is defined by the sociocultural milieu in which the work is performed, which, together with the materials, tools, and other features of the environment, provide constraints in which creativity thrives. Indeed, creativity involves the cycling through acting and evaluating outcomes in such a way as to imply a closely coupled, dynamic feedback loop.[5]

As shown in chapter 5, the notion of "patterns" informs ecological interface design. Such patterns can also be explained by the phrase information-as-context, which I use in the book as a gloss on some of Gibson's ideas. Moreover, emphasis on pattern, symmetry, harmony, and balance echoes advice that can be found in any textbook on art, architecture, jewelry-making or any other form of creative practice. Knowing that certain patterns seem particularly salient to human perception, one can assume that "good" design (at least as far as one considers the form of an artifact) will carry with it some sense of the designer's interpretation of proportion, symmetry, harmony, or balance, each of which represents different objectives that the designer is using to constrain the design, In this way, the "outcome" of the design has, inherent in its definition, some or all of these concepts.

From this perspective, the role that a mental model has in design practice could be minimal. Rather, the physical interactions change the states of the human-artifact-environment in ways that create new opportunities for action and new affordances for activity to move to new states. For Sawyer and de Zutter,[6] creativity is opportunistic in that the creative practitioner responds to the "micro-affordances" that arise from their ongoing, reciprocal interaction with their environment (and the materials it contains). In this moment-by-moment shifting of contingency, potential synergies arise and provide constraints on potential actions. My intention is not to deny or denigrate people's experiences of creative practice. If the phenomenology of creativity involves a strong sense of ideas coming from inside the head (or from external muses or divine inspiration), I am not seeking to destroy such beliefs. Indeed, prodding such experiences might damage the very practice we wish to understand. As a surgeon once remarked to me when I was questioning how he made sense of his skill and practice, "There are better ways of understanding how a watch works than pulling it to pieces," especially (and here he looked over his half-moon spectacles at me) "if one is not a watch-maker." But, in my experience, creative practitioners are less likely to speak of ideas being fully formed in their heads and then made by their hands than to have a feeling in which a form reveals itself as material is being worked (or a form resisting particular demands of the maker). From an information-processing account, it is easy to dismiss the idea of a "form waiting to be found" as mysticism. Yet, this does seem to be a valid experience of many craftspeople.

As an example of this way of thinking, recall Karl Marx's contrast between spiders, bees, and humans:

> A spider conducts operations that resemble those of a weaver, and a bee puts to shame many an architect in the construction of her cells. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in imagination before he erects it in reality. At the end of every labour-process, we get a result that already existed in the imagination of the labourer at its commencement. He not only effects a change of form in the material on which he works, but he also realises a purpose of his own that gives the law to his modus operandi, and to which he must subordinate his will. And this subordination is

no mere momentary act. Besides the exertion of the bodily organs, the process demands that, during the whole operation, the workman's will be steadily in consonance with his purpose. This means close attention.[7]

The first part of the quotation echoes Aristotle's notion of "hylomorphism." Ingold[8] points out that typical accounts of creativity seem to assume a chain of causality from "idea" to "artifact." However, this is in stark contrast to the observations of artists and designers who might recognize the statement that "design is always a search for something that is unknown in advance."[9] In other words, creative practice more likely involves an interplay between forming (as a process of physical manipulation of materials) and thinking (as a process of evaluating and anticipating forms as they are made). Marx says that the "will" is in consonance with the purpose. In other words, the loose coupling within the human-artifact-environment system involves an ebb and flow of control, from person to environment and back. In this way, "creativity" could be a matter of sensitivity to changes in the way that we interact with the world around us. This is similar to Ingold's argument about creativity as improvisation.[10] In improvisation, there is a sense of foresight (rather than prediction) in which one is able to see, from a given point in time, a few steps into the future (but not to the very end of the creative process). This sense of improvisation would suggest that the designer responds to affordances in a current state as a means of spotting opportunities for action to transition to another state (e.g., through exploratory sketches, model-making, or working with different materials).

The Importance of Task Ecologies

To better understand how the human-artifact-environment system works, the notion of task ecology was discussed in chapter 3. In this, the ecological niche provides the resources for action, and here, the "ecological niche" consists not only of physical features but also of cultural conventions and practices. Good design is aware of these interconnecting features of the ecological niche. Indeed, I would go as far as to say that good design is concerned with the creation of ecological niches as much as it is with the creation of artifacts. While this claim might make sense when speaking of architecture (which, as a discipline, has a strong tradition of theory, much of which chimes with the points I am making in this book), I believe that it is also true of single artifacts. In essence, the design is constraining the objectives (of the human-artifact-environment system) in such a way that activities become apparent and that, for each of these activities, the artifact can be "ready-to-hand." It is my contention that theories of design that see the artifact as the "solution" to a problem not only inherit some of the thinking from information processing that I have pointed out in this book, but also create overly constrained designs.

Even for a trivial information display, the notion of task ecology can be instructive. In an analogue clock (figure 8.2a), the numbers on the clock face and the moving hands indicate a specific form of information that supports a specific enquiry—namely, what is the time now? For other decisions, it is necessary to manipulate this information. So, the clock answers the question what is the time, but not questions such as can I make the next train? or how much longer is left for this lesson? The TimeTimer design, in contrast (figure 8.2b), supports the latter query by color-coding a region that indicates when the lesson in meant to finish (if lessons begin on the hour and end after 45 minutes, we add a red band on the clock face). It does not, of course, allow us to answer the question "What time is it now?"

The modification of the display is intended to support a specific enquiry—so the space of possibilities is open (for the clock) and closed (for the TimeTimer). As the environment becomes richer in information, the challenge of closing the space of possibilities for specific enquiries becomes greater, particularly when information sources increase, or some sources are more reliable than others, or when there are "incomplete invariants."[11] Having said this, I would note that the TimeTimer is an example of a design in which the task ecology matches a specific goal in such a way as to support "direct perception"; in other words, the person is able to perform a specific task without manipulating the information. That is, it affords the task of deciding when a lesson is (or should be) ended—assuming that the person understands what the color indicates, that the clock time is correct, and so on.

While the TimeTimer introduces the idea of designing products to suit highly specific goals, I am not arguing for this as a general approach to design—not least because it encourages a commitment to "modes" (that is, highly constrained states of a product that are only appropriate for a single activity). While there might be places in which modes are beneficial, the general consensus in human-computer interaction (HCI), and design in general, is that these ought to be avoided because they limit the functionality and utility of a product. However, we can learn from this example that

Figure 8.2
(a) Analogue clock and (b) the TimeTimer countdown clock.

the space of possibilities offered by an artifact can provide constraints on action. The ecological interface design approach, considered in chapter 5, draws attention to the ways in which an understanding of constraints can benefit design thinking. These constraints, of course, apply only under certain conditions—for example, TimeTimer assumes an environment in which activity has a duration of forty-five minutes and that humans know the convention that the activity will end after this duration. What this artifact "affords" depends on the nature of the activities permitted within this environment and the conventions surrounding these. For example, is it acceptable for pupils in the classroom to start gathering their belongings together and standing up to leave when the hand has passed the forty-minute mark? Should the teacher beginning summarizing the lesson at thirty-five minutes? These questions also point to the reason why problem-solving is a poor metaphor for design; it implies that there is an impetus to produce a "solution" that can be expressed in a form. But a "poor" design may prematurely commit to a single state and constrain opportunities for new states to arise. This is another reason why the use of "modes" is frowned upon in design.

Affordances

A designer cannot simply imbue an artifact with a specific property and expect this artifact to possess an "affordance." Indeed, what does the idea of giving an artifact an affordance mean? I have argued against a notion of affordance as "artifact x affords action y." If affordances guide action, then this could only be the case for an agent able to perceive relevant "information," able to perform the relevant action, and able to relate the action to a desirable goal. In other words, design is not a simple matter of "fossilizing" a single affordance (i.e., a defined state of the human-artifact-environment system). If so, whose affordance and for what purpose? Alternatively, should design reflect as broad a range of potential affordances as possible, each arising from different states of the human-artifact-environment system (even ones that the designer has not yet considered)? In some instances, there may be overlap between these different states for some coherence and consistency to appear (or the ways that humans adapt their actions to the form of the artifact might allow consistent patterns of action to apply). What the designer is doing is not simply specifying a form but also laying out the affordances in which this artifact participates. As I noted in chapter 4, affordances are *not* merely properties of the artifact (if they were, then that would mean that an "affordance" is trivially the same as the "function" supported by the "form" of the artifact). Rather, affordances are the states in which the human-artifact-environment system finds stability. By defining these potential states, the designer is exploring the *some* of the range of uses, interactions, activities in which the artifact can participate.

The concept of affordance makes sense as emerging from a human-artifact-environment system in which the environment (and the artifacts it contains) combine with the human (and their capabilities) to create a set of constraints under which activity is performed. These constraints are further modified by the task constraints (relating to conventions surrounding the definition of a goal, criteria for the quality of performance, and so on) such that executability conditions influence the constraints within which the person can act. The action possibilities, in turn, become “intentions.” If we reverse this process, then the perception of features or performance of actions can create higher-level goals.

In order to explore the concept of affordance further, and to simplify the idea that there are different levels of “affordance,” I developed the idea of forms of engagement.[12] In this, the focus is on the ways in which we engage with artifacts and how different forms can serve to support and constrain each other. The most recent version of this concept is illustrated by figure 8.3. The arrows are intended to indicate the relation “constraints.” At the center of figure 8.3 is a dotted box labeled “affordance.” This describes a relationship between the ability to recognize salient features in an artifact (environmental engagement) and the ability to act using that artifact (motor engagement).

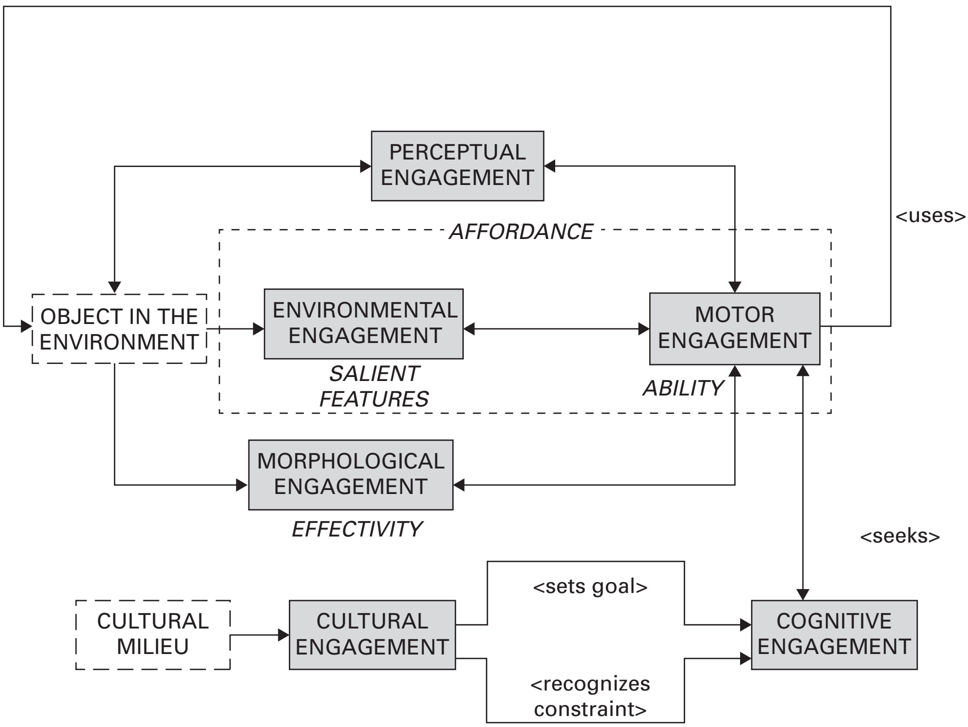

Figure 8.3
Forms of engagement.

Figure 8.3 separates the effectivity of the person, in terms of morphological engagement, which influences how an artifact is grasped, from the ability to reach for or manipulate that artifact, in terms of motor engagement. There are two reasons for this: first, morphology is partly dispositional, for example, in terms of the size of the hand; and second, hand shaping will be influenced by subsequent actions—for example, when reaching to grasp an artifact, hand shape is modified in anticipation of the type of grip required to respond to properties of the artifact, such as weight, fullness, slipperiness, and the like, and this will also be influenced by motor engagement, seeking, for example, "end-state comfort."[13] The assumption is that there is a set of ways in which an artifact can be grasped by the human hand and that the selection of grasp combines artifact properties with intended action. That is, a hand of a given size will have limits as to how it can grasp artifacts, but how the grasp is performed reflects the ability and intentions of the person, which will vary according to a host of situational factors, as well as prior experience.

In order to act on an artifact, there is a need to respond to the "information" that it conveys; that is, information-as-context constrains environmental engagement. Consequently, an affordance arises as the result of the relationship between features perceived through environmental engagement and action performed using motor engagement. We can directly relate this proposal to the formal descriptions of affordance—for instance, imagine we are interested in stair-climbing, and the property of the world is the height of a stair riser, and the property of the person is their leg length. This "perception-action coupling" is the specific relationship between artifact and action and is an emerging property of the world-artifact-person system. However, the relationship is bounded by the other forms of engagement. The suggestion that motor engagement is directed toward subsequent action implies an intention, but I argue that there is equal scope that the "intention" can be defined in response to the motor engagement (i.e., as opportunistic or situated action). At the very least, there is a two-way exchange between the action-as-performed and the goal-state of that action. The role of cognitive engagement is to provide this high-level management to ongoing actions. Across the various forms of engagement, perceptual engagement relates salient features to changing states of the artifact-person system. Finally, the notion of an "acceptable" goal could relate to the culture in which one is acting. This cultural engagement relates to the idea of "cultural affordances"[14] and, as Davis[15] has so clearly explained, carries with it a host of political and social markers. Forms of engagement is still being developed and needs, for example, consideration of "effective engagement" (which was originally assumed to be part of "cultural engagement" but needs it own description).

Activity and Intent

When should a person stop an activity to "off-load" tasks, or when should the agent interrupt a person's activity with the results of its search? Neither of these issues is trivial, because both depend on the context in which the activity is being performed. From this perspective, the use of technology to support embodied cognition could require the explicit ability (in the technology) to recognize what a person is doing, when interruptions are permissible, how much information to provide, and so on, all of which places the locus of control in the technology.

When we design technology to manage information-as-content, the illusion of "locus of control" is not difficult to maintain. The human issues a request, and the computer provides a response, even if, hidden in this interaction, there is "smart" technology that interprets the request or that determines a request that matches a profile of the requester (as with recommender systems). In this case, it might *feel* as if "agency" lies with the human, but this might simply be because we assume a cause-effect relationship between request and response and see none of the mediation that occurs. In the examples in which the "smart" technology initiates an action because it anticipates or predicts what the user requires, do we assume that it agency is ceded to it? Certainly, we might complain that these smart technologies are operating outside of our control. This might be because there is a lack of transparency in what data they are using or what algorithms they are running; in some cases, we might not even be aware that we are being subjected to data collection. Equally, the smart technology might perform actions that, while they accord with its algorithms, make little sense to the people affected by them. Under these circumstances, speaking of human-computer *interaction* makes little sense because there is no opportunity for "interaction." In these situations, our relationship with technology has the hallmark of the irony of automation: we are the object of the computer's algorithm and the subject of its data harvesting but have little ability to manage either. However, the consequences of an action that we perform that has been indicated by the computer may well be our responsibility (rather than the responsibility of either the computer or its manufacturer).

If we accept that "intention" arises from the state of the system, then it makes much more sense to consider ways in which to communicate this intention (as opposed to the immediate inputs and outputs of information-processing). In other words, it might be more useful to know under what constraints information is being collected and processed—for example, what are the goals that are being pursued and who benefits from these? This approach would shift the focus from moment-by-moment data processing and toward the definition of boundaries of the system (who and what are affected?, what are the upper and lower limits of the system's activity?) and borders (where and how will information be exchanged?). In our everyday life, our interactions with other people are bounded and bordered by a host of conventions that we take for granted (and become aware of only when we encounter situations that are unfamiliar to us). We modify our behavior in response to cues from the situation, in terms of how people are behaving and speaking, for example, or how our conversation partner is responding to what we are saying, and so on. None of these cues is marked explicitly, so they do not constitute information-as-content; rather what they do is help to shape the ecological niches in which our activity occurs. In much the same way, the design of, say, supermarket aisles and product displays is intended to provide information-as-context to encourage ways of moving through the store and "impulse buying" as much as information-as-content in labels, price tags, and signage. We probably pay very little attention to the information-as-context, and few of us challenge (or know how to challenge) the layout of the supermarket because our interaction with it is implicit. However, in the supermarket, we still have the opportunity to act in a way that allows us to retain the sense of agency; we continue to believe that we choose which aisle to walk down and which products to buy. At present, smart technology can often feel as though it has taken Negroponte's concept of the smart refrigerator to a *reductio ad absurdum*, as if the fridge not only decides what to buy, but makes the order and then expects us to pay for it and put it away when the delivery arrives.

What Is Wrong with "User-Centered" Design?

Design thinking shares with HCI, ergonomics, and systems engineering a recognition that design ought to be "user-centered." Indeed, to suggest that design might be anything but centered on the user might feel like heresy. It is not my intention to claim that the "user" should not be considered, or have a role, in the practice of design, or that products should not be "usable." But I do question whether "user-centered" simply means asking the user what they want. Such concerns have been voiced by many researchers in the past.[16] There are many well-known and oft-repeated problems that arise from relying solely on user opinion to define requirements for design. For example, users might base their requirements on what they know, or what other products they have seen (e.g., Henry Ford's observation that people wanted a faster horse rather than the automobile). Users struggle to provide clear, unambiguous, and consistent definitions of their actual need; so, they change their minds or contradict themselves, or add to their list of requirements (particularly when they are shown the initial design concept). Add to these the challenge of deciding "who" the user of a product might be, and you appreciate why "user-centered" might be a fig leaf to cover either formal methods (in systems engineering) or the autocratic author (in product design). But user-centered design (and the need to engage with users) is a mandatory part of HCI, with International Standards prescribing a need for this. For example, ISO 13407 defines "usability" partly in terms of measures (efficiency, effectiveness, and user attitude when using a product to perform a task) and partly in terms of "context of use." The latter involves the combination of user (in terms of knowledge, skills, abilities), goal to be achieved, tasks required to achieve the goal, environmental conditions, and other equipment to be used. This notion of context of use chimes with many aspects of design thinking, and the majority of the methods that are advocated in design thinking, or HCI, or ergonomics tends to be more concerned with capturing these elements of a context of use than they are with creativity or generating design concepts.

The idea of context of use also leads to Bardram's notion of activity-based computing. From this, the essential aspects of defining user requirements lies in observing the activity that people do in the environment in which they will be using the product. How one conducts such observations is the basis of the different methods and part of the turf war between disciplines. For ergonomists, the primary approaches involve either task analysis (with its roots in time-and-motion study and information-processing psychology) or cognitive work analysis (chapter 5). A criticism leveled against these approaches is that they are overly reductionistic and fail to capture the subtleties of the context.

Against these "formal" methods, ethnographic approaches produce rich descriptions of the context in which people experience their technology (this approach is considered in chapter 3). We have noted that ethnomethodology in HCI has sought to produce rich descriptions of this complexity, but we have also argued that the reliance on verbal descriptions could miss some of the ways in which the human-artifact-environment system operates. This omission is, as argued above, due to the limits of using words to describe the system. It is also due to the challenge of taking specific instances that have been observed and working from these to general principles. Admittedly, ethnomethodologists might be reluctant to accept that their work *could* be generalized; after all, the richness of the description arises from the specific instance. But, placing this work in the domain of HCI (or design more generally) means that there must be an intention for designers and developers to respond to this work, and this (irrespective of the analysts' intention) means that the results of such studies would be translated into requirements, specifications, and design objectives. In other words, we need to have a "guide for discovery."

Both research traditions focus on capturing the context, but neither offers substantial support for the practice of design. Indeed, both approaches produce documents (complex diagrams from ergonomics, reportage from ethnography), which are more or less handed over to the designer to interpret. HCI has been divided between approaches to evaluation that emphasize "usability" (covered by the International Standards and with its root it ergonomics) and "user experience" (with roots that can be traced to the ethnographic approaches used in HCI). As noted above, ISO 13407 would expect both approaches (user attitude is, after all, a reflection of user experience).

To return to our discussion, the question is what does it mean to "center" design on users? If asking them what they want is problematic or observing them in situ is either reductionistic or superficial, what is left? My impression is that the experienced designer seeks to define a particular situation (or "context of use"). The description of the context of use can be obtained and reviewed by speaking to people, watching them, experiencing the situation oneself, or creating scenarios, stories, or prototypes. Each of these broad approaches (and the countless methods associated with them) is used to recast the context of use into terms that are amenable to design. The methods that are used (and the baggage that they bring with them) become less important than the overarching design to reach consensus on this context of use. What shifts design from a mundane task of problem-solving to something more difficult is that the problems are typically "wicked" and their solution involves optimizing multiple objectives (not least because the idea of a "consensus" can be hugely challenging). By understanding context of use as the ecological niche for the potential users of the artifact and by appreciating how the affordances offered by the artifact create opportunities for action, design practice involves the broad and deep appreciation of the potential states in which specific human-artifact-environment systems can function. In order to do understand context of use, accounts that draw on phenomenology and ethnography (e.g., through reportage, conversation analysis, video analysis) provide the breadth of understanding. However, in order to achieve the depth, it is also important to remember Brunswik's notion of "ecological validity" and to specify the ways in which the environment and activity acquire salience. My proposal is that this requires analysis that can capture the micro-materialities of states of the human-artifact-environment system (e.g., through data from eye-tracking or sensors on the person or the artifact). This fine-grained analysis of micro-materialities is not intended to reflect discrete actions (which would, I think, do little to complement the detail in phenomenological accounts) but should be analyzed in terms of the stability of the system—that is, in terms of how the balance between variability and consistency is maintained by the application of metrics that describe entropy and that use techniques from dynamic systems. This marriage of phenomenology and dynamic systems is at the very heart of RECS and, I propose, offers opportunities for development of digital technology (in terms of recognizing activity and intent as well as in terms of more deeply understanding human interaction with these technologies).

HCI has been concerned with the lived experience of everyday interactions with digital technology, or what Dourish calls "everyday mundane experience."[17] Dourish's approach derives from particular readings of phenomenology (drawing principally on aspects of the work of Heidegger and Merleau-Ponty). For Dourish,[18] in his pioneering work on embodiment in human-computer interaction, meaning involves three elements. The first two develop from his reading of Merleau-Ponty and his insistence on "intentionality" and "ontological commitment." In terms of the former, Dourish uses the phrase "coupling" to elucidate this: "By coupling, I mean the way that we can build up and break down relationships between entities, putting them together or taking them apart for the purpose of incorporating them into our action."[19] I understand this idea of coupling as being similar to Gibson's "complementarity" or Ingold's "co-respondance." which relate to the experience of purposefully interacting within an ecological niche. How we recognize and realize the material and functional environment can depend on the constraints within which we act. So, there would be differences between the experiences of a designer and user of a product; both can approach the same physical form from different ontological commitments. At issue, is the extent to which the material or the functional environment becomes influenced by the form or the function of the artifact, and how this influences action.

What Can Design and Creativity Tell Radical Embodied Cognitive Science?

For its critics "representation-hungry" cognition, such as abstract thinking and creativity, lie outside the realms of embodied cognition. The argument is that, while embodied approaches can deal with physical actions (and while there might a grudging admission that embodied cognition can provide reasonable accounts of problem-solving tasks that rely on physical artifacts), it is unable to cope with "higher-order" cognition. In part this argument relies on the assumption that there needs to be internal representation in order to "do" cognition. These "higher-order" cognitive activities, for information processing, require the creation and manipulation of internal representations that are built on top of existing internal representations. The tautology of the argument (that internal representations are needed to create internal representations) undermines the argument, but still, if there is no need for internal representation, then how can this higher-order cognition occur?

I believe that RECS provides a clear description of creative practice that feels as if it has far more in common with the experience of practitioners than the information-processing approaches. Creativity requires a repertoire of responses (in terms of the ability to work with materials, to produce models, to make sketches, and so on) that are acquired from the practice and experience of designing. These responses provide a means of interpreting and responding to constraints within the problem space. My reading of

RECS sees creativity as the opportunistic response to constraints. Indeed, creativity seems to thrive with constraints; that is, people are more likely to produce solutions that are rated as "creative" when there are *some* constraints than when there are no constraints.[20]

In a similar vein, for the skilled intentionality framework (SIF), higher-order cognition does not depend on internal representations. In part this is because human activity is performed in a "rich landscape of affordances," which are responded to on the basis of the lived experience of each of us. Recall that affordances, in this book, relate to states of the human-artifact-environment system that can be considered as objectives for transitions to and from. First, the environment (as a socio-material construct) has a host of constraints on what actions are performable (in physical terms) and permissible (in outcome terms). Second, the notions of performable and permissible will be informed by the lived experience of each individual. If we share similar cultural upbringing, then we might also share similar notions of what is permissible. The notion of creativity advanced in this book is one in which activity seeks to discover the limits of the constraints (through tightening or loosening one or two of these to be objectives for the system's transitions). In the words of Withagen and van der Kamp, "Creativity can be conceived as the discovery and creation of unconventional affordances."[21] This could easily become a trial-and-error form of activity (or, in artificial intelligence terms, a form of "explore and exploit" activity). It should not, I think, be seen as aimless, reckless, or unstructured—because the precursor to such activity is the identification of constraints to modify. So, in part, higher-order cognition arises from identifying and manipulating the constraints in the human-artifact-environment system. As new states of the system arise, so these need to be evaluated (in terms of affordances or in terms of permissible outcomes). None of this requires internal representation. But advocates of information-processing approaches might feel that this account is overly mechanistic and that it does not provide an indication of how things such as "insight" might arise.

Notwithstanding that many advocates of the information-processing approach dislike the notion of "insight" (because it does not conform to the production line of cognition that the approach assumes), I feel that this complaint misses two essential issues. First, RECS (and SIF and other approaches to embodied cognition) recognizes that human activity is part of the ongoing, lived experience of the individual. For RECS, an activity not only occurs in the human-artifact-environment system but does so in terms of the history of the individual's history of prior interactions. This is partly in terms of solutions to the degrees of freedom problem that has previously been applied, both in terms defining of physical movement in terms of coordinative structures and in terms of selecting and responding to sense data, e.g., in terms of information-as-context. It is also partly in terms of the history of the environment and the artifact (which might be modified as the result of previous activities upon them). This activity is not and cannot be (as information-processing approaches so often imply) discrete, boxed off, and separated from our history of activity. In the laboratory, are we really to assume that the participant forgets everything she knows and focuses only on the task instructions and the task materials in front of her? Even if this were the case, are we sure that these task materials provide sufficient ecological validity to be a fair test of the whatever activity under investigation? In terms of "insight" (as we saw in chapter 2) a reasonable explanation (and one that does not require us to conjure solutions to a problem out of thin air) is that participants respond to affordances in the context of the problem-solving task and that these create opportunities for action. Similarly, epistemic action in problem-solving capitalizes on this activity. Whether the environment is the design studio, the jeweler's workshop, the keyboard of a piano, or the canvas on an easel, the activity of the human responds to its properties and changes it. In this way, creativity is simply the dynamic interplay between the artist or designer and their environment. Or rather, it is the continual reciprocal engagement between elements in the human-artifact-environment system.

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An Applied Science of Radical Embodied Cognition

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