CHAPTER 5

Modern Theories

In the late 1980s, it became increasingly apparent that the early attempts at importing cognitive psychology theories were failing to live up to their expectations. Several researchers began to reflect on why this was the case, especially why they were unable to be more widely applied to the problems of design and computer use (e.g., Long and Dowell, 1996). There was much navel-gazing, cumulating in the realization that classical cognitive theories were inadequately formulated for informing system design (see Carroll, 1991). A number of problems were identified, including that the theories were too low level, restricted in their scope and failed to deal with real world contexts (Barnard, 1991). The failings of a "one-stream" approach, whereby it was assumed that mainstream theory provided by pure science (i.e., cognitive psychology) could trickle down into the applied science of designing computer systems were exposed (see Long and Dowell, 1996). There was even criticism that psychologists were merely using the field of HCI as a test bed for trying out their general cognitive theories (Bannon and Bødker, 1991) or for validating the assumptions behind specific models (Barnard and May, 1999).

It was still hoped that theory could make a valuable contribution in HCI. The question raised by all this introspection, however, was what kind of theory and what role should it play? Several prominent researchers began to push for other approaches. Long and Dowell (1989, 1996), for example, made persistent calls for more domain-specific theories that could focus on the concerns of users interacting with computers to enable them to work effectively. Carroll et al. (1991) argued that users and designers would benefit more if the process by which tasks and artifacts co-evolved could be "better understood, articulated and critiqued" (p99).

Others revised and adapted their cognitive frameworks to be more representative and build directly on the concerns of HCI (e.g., Draper, 1992). New cognitive theories emerged that focused on interactivity rather than solely modeling what was assumed to happen "inside the head." It was recognized that a more appropriate conceptualization of cognition for HCI was one that was distributed across people, technologies and the environment and externalized. A central focus was the interplay between external representations and internal representations at the interface (e.g., Green et al., 1996; Hutchins, 1995; Kirsh, 1997; Scaife and Rogers, 1996; Wright et al., 2000).

There were also attempts to look for different theories that took into account how the environment affected human action and perception. Several ideas from ecological psychology were imported into HCI (e.g., Gaver, 1991; Norman, 1988). Other researchers began looking elsewhere for theories that were more encompassing, and which could address the concerns of interacting with computers in real-world contexts. By changing the boundaries of what was studied, and by looking at the phenomena of interest with different theoretical lenses and methods, it was assumed that a new set of research questions could be framed, which, in turn, could feed into the design of more usable computer artifacts (Bannon and Bødker, 1991).

Concomitantly, there was a "turn to the social" (Button, 1993): sociologists, anthropologists and others in the social sciences joined HCI, bringing with them new frameworks, theories and ideas about technology use and system design. Human-computer interactions were conceptualized as social phenomena (e.g., Heath and Luff, 1991). Most notable was the situated action (SA) approach and ethnography. A main thrust of the SA approach was to examine the *context* in which users interact with technologies: or put in social terms, how people use their particular circumstances to achieve intelligent action.

The approach known as ethnomethodology (Garfinkel, 1967; Garfinkel and Sacks, 1970) provided much of the conceptual and methodological underpinning for the early ethnography in HCI (Button, 1993). It offered new ways of describing the informal aspects of work, i.e., "the hurly burly of social relations in the workplace and locally specific skills required to perform any task" (Anderson, 1994, p154).

Table 5.1 shows each of the Modern theoretical approaches that are covered, outlining their origins, appropriation in HCI, their impact on research and practice and an "in a nutshell" description. Their selection and amount of coverage is based on their influence in HCI. A section on CSCW theories is also included to show how theory was instrumental in the establishment of that field.

Table 5.1: Modern Theoretical Approaches in HCI

Alternative cognitive approaches	
	5.1 External cognition
	5.2 Distributed cognition
	5.3 Ecological psychology
Social approaches	
	5.4 Situated action
	5.5 Ethnomethodology and ethnography
	5.6 CSCW theories
Other imported approaches	
	5.7 Activity theory
	5.8 Grounded theory
	5.9 Hybrid theories

5.1 EXTERNAL COGNITION

Larkin and Simon's (1987) classic cognitive science paper on why a diagram may be worth a thousand words became a landmark in HCI because it offered the first alternative computational account of cognition which focused on how people interact with external representations. Their seminal idea was that cognition be viewed as the interplay between internal and external representations, rather than only be about modeling what was assumed to happen inside the head. It was regarded by those who had become disaffected by cognitive models as a source of inspiration for rethinking HCI and for me, personally, provided an "aha" moment, leading to the development of a new theory of external cognition (see Rogers, 2008a).

Larkin and Simon's theoretical account made an important distinction between two kinds of external representation: diagrammatic and sentential representations. While being *informationally* equivalent they were considered to be *computationally* different. That is they contain the same information about the problem but the amount of cognitive effort required to come to the solution differed. They proposed that solutions to problems could be "read off" from diagrams that were implicit in sentences. People can readily switch their attention from one component to another in a diagram to draw conclusions in ways that are impossible to do with a sequence of sentences. Diagrams provide simultaneous information about the location of components in a form that enables objects and their relations to be easily tracked and maintained. From this, we can deduce that the best diagrams are those that make it obvious where to look to draw conclusions.

Larkin and Simon's paper paved the way for HCI researchers to begin in earnest to theorize the role of external representations in human-computer interactions. There was a palpable buzz in the early 1990s as they endeavored to change the face of theorizing in HCI. O'Malley and Draper (1992) proposed a display-based account that differentiated between the knowledge users need to internalize when learning to use display-based word processors (e.g., Word) and the knowledge that they can always depend upon being available in the external display. Norman (1993) had a big impact, popularizing the notion that knowledge resides both in "the head" and in "the world." Wright et al. (2000) developed a resource model that analyzed internal (e.g., memorized procedure) and external representations (e.g., written instructions). Kirsh (1997) developed a theory of interactivity that stressed how cognition can be extended in a variety of ways in what we can do, and allowing us to think more powerfully As well as reducing the cognitive effort that is needed to perform tasks, he argued that we should reframe external representations in terms of how they can enhance cognitive power. He suggested a number of ways, including providing a structure that can serve as a shareable object of thought; creating persistent referents; facilitating re-representation and the computation of more explicit encoding of information and helping to coordinate thought. A core aspect of interactivity is the ability to project structure onto things and then modify the world to materialize or reify that projection. People often reorder or rearrange objects in the environment, such as shuffling the letters around in a Scrabble tray to help them work out the best word given their set of letters (Maglio et al., 1999). Kirsh (2010) also stresses how we are always creating external representations; on the one hand they can help reduce memory load and the cognitive cost of computational tasks but, equally, they can do and allow us to think more powerfully.

The theory of external cognition was developed to systematically inform how new technologies, such as animations, multi-media and virtual reality could extend and enhance cognition

(Rogers and Scaife, 1998; Scaife and Rogers, 1996). A number of core dimensions were identified that could be used to guide the design of different kinds of external representations that would be of "added" cognitive value for particular users, domains and tasks. It suggested how interactive mechanisms enabled by computer technologies could be exploited to guide and scaffold learners in knowing where to look in order to interpret, make inferences and connections between the different elements of a graphical representation.

External Cognition in a Nutshell

A central property of external cognition is *computational offloading* — the extent to which different external representations vary the amount of cognitive effort required to carry out different activities (Scaife and Rogers, 1996). This is broken down into specific design dimensions, intended to guide the design of interactive representations. They include *re-representation* (how different external representations, that have the same abstract structure, make problem-solving easier or more difficult) and *graphical constraining* (how elements in a graphical representation are able to constrain the kinds of inferences that can be made about the underlying represented concept). The dimensions were further characterized in terms of design concepts with the purpose of framing questions, issues and trade-offs. Examples of design concepts are *cognitive tracing*, which refers to the way users are allowed to develop their own understanding and external memory of a representation of a topic by being allowed to modify and annotate it; *explicitness* and *visibility* which refers to how to make more salient certain aspects of a display such that they can be perceived and comprehended appropriately. Another design concept is *dynalinking*, which refers to how abstract representations, such as diagrams, are linked together with a more concrete illustration of what they stand for, such as a simulation. Changes in one are matched by changes in the other, enabling a better understanding of what the abstraction means.

The set of external cognition concepts were intended to suggest to designers ways of generating possible functions at the interface. For example, Masterman and Rogers (2002) developed a number of online activities that allowed children to create their own cognitive traces when learning about chronology using an interactive multimedia application. They have also been used for deciding how to design and combine interactive external representations for representing difficult subjects, such as dynamical systems in biology, chronology in history, the working of the cardiac system and crystallography (e.g., Gabrielli et al., 2000; Masterman and Rogers, 2002; Otero, 2003; Price, 2002). Sutcliffe (2000) has also shown how he used the theory to inform the design of multimedia explanations. The approach was also applied in work settings, to inform the design of online graphical representations that could facilitate and support complex distributed problem solving (Rodden et al., 2003; Scaife et al., 2002). Dynalinking has been used in a number of areas to explicitly show relationships among multiple dimensions where the information to be understood or learned is complex (Sutcliffe, 2000). For example, it has been used to represent complex data using various interactive visualizations, for domains like learning science subjects, economic forecasting, molecular modeling, and statistical analyses.

Other analytic frameworks that were developed under the umbrella of the external cognition approach include Green's (1989) cognitive dimensions and Wright et al.'s (2000) resource model.

5.1.1 COGNITIVE DIMENSIONS

Cognitive dimensions were intended to enable psychologists and importantly, designers, to make sense of and use when talking together about design issues. Green's overarching goal was to develop a set of high-level concepts that were both valuable and easy to use for evaluating the designs and assessment of informational artifacts, such as software applications. An example dimension is "viscosity," which simply refers to resistance to local change. The analogy of stirring a spoon in treacle (high viscosity) versus milk (low viscosity) quickly gives the idea. Having understood the concept in a familiar context, Green then showed how the dimension could be further explored to describe the various aspects of interacting with the information structure of a software application. In a nutshell, the concept is used to examine "how much work you have to do if you change your mind" (Green, 1990, p79). Different kinds of viscosity were described, such as "knock-on' viscosity," where performing one goal-related action makes necessary the performance of a whole train of extraneous actions. The reason for this is due to constraint density: the new structure that results from performing the first action violates some constraint, which must be rectified by the second action, which in turn leads to a different violation, and so on. An example is editing a document using a word processor without widow control. The action of inserting a sentence at the beginning of the document can have a knock-on effect whereby the user must then go through the rest of the document to check that all the headers and bodies of text still lie on the same page.

The approach was meant to be broad-brush, and importantly, comprehensible to and usable by non-specialists. The original set of terms comprised a small vocabulary of about 12 terms that describe aspects of user interaction that are cognitively relevant. Besides viscosity, they included premature commitment ("are there strong constraints in terms of the order of how tasks are to be carried out?"), diffuseness ("how much space does the notation require to produce a certain result or express a meaning?") and visibility ("how readily can required parts of the notation be identified, accessed and made visible?"). Some are more intuitive to understand than others. One of Green's claims about the value of cognitive dimensions is that by identifying different kinds of dimensions at a suitable level of abstraction across applications, solutions found in one domain may be applicable to similar problems found in others.

Although never widely used, the lingua franca of "cog dims" has been influential. In particular, it has been used to determine why some interfaces are more effective than others. These include educational multimedia (e.g., Oliver, 1997; Price, 2002), collaborative writing (Woods, 1995), tangible user interfaces (Edge and Blackwell, 2006) and programming environments (Modugno et al., 1994; Yang et al., 1995). Kadoda et al. (1999) and Blackwell and Green (2000) also extended the approach by developing a generalized questionnaire in which the definitions of cog dims are provided for users rather than designers, who decide for themselves the features of a system that they wish to criticize. Designers and researchers who have been exposed to them for the first time have found them comprehensible, requiring not too much effort to understand and to learn how to use (Green et al., 1996). Indeed, when one first encounters the cog dims there is a certain quality about them that lends to articulation. They invite one to consider explicitly trade-offs in design solutions that might otherwise go unnoticed and which, importantly, can be traced to the cognitive phenomena they are derived from.

5.1.2 WRIGHT ET AL.'S RESOURCES MODEL

Wright et al. (2000) modeled external cognition in terms of *resources* that are drawn upon during user interaction. They categorized these in terms of plans, goals, possibilities, history, actions-effect relations or states. They could be represented internally (e.g., memorized procedure) or externally (e.g., written instructions). Configurations of these resources, distributed across internal and external representations, were assumed to be what informs an action. In addition, the way the resources are configured in the first place, is assumed to come about through various "interaction strategies." These include things like plan following and goal matching. Thus, a user's selection of a given action may arise through an internal goal matching strategy (e.g., delete the file) being activated in conjunction with an external "cause-effect relation" being perceived, (e.g., a dialog box popping up on the screen saying 'are you sure you want to delete this file?').

Wright et al.'s (2000) analytic framework identified patterns of interaction together with the variability of resources that are used at different stages of a task — such as determining when a user can depend on the external resources (e.g., action-effect relations) to constrain what to do next and when they must rely more on their own internal resources (e.g., plans, goals and history of actions). The idea was that the analyst could reflect on the problems with a given interface in terms of the demands the various patterns of resources place on the user.

What impact has external cognition had on HCI?

One of the main uses of the external cognition approach in HCI has been to enable researchers and designers to articulate designs and phenomena in terms of a set of core properties and design dimensions — which they did not have access to before. In so doing, a language, couched in how people manipulate representations, interact with objects, etc., at an interface, was provided, helping researchers to select, articulate and validate particular forms of external representation in terms of how they could support various activities being designed for. Besides the originators of the theoretical frameworks, they have been used by a number of others to inform the design of various interfaces. Their emphasis on determining the optimal way of structuring and presenting interactive content with respect to the cognitive effort involved can be viewed as being generative Although largely superseded by contemporary theories that address a broader range of user aspects, the extended cognition approach still has much to offer in terms of helping designers select and create interactive visualizations, feedback and multi-modal representations.

5.2 DISTRIBUTED COGNITION

The distributed cognition approach considers cognitive phenomena in terms of individuals, artifacts, and internal and external representations (Hutchins, 1995). It provides a more extensive account compared with external cognition. Typically, it involves describing a "cognitive system," which entails interactions among people, the artifacts they use, and the environment they are working in. It was initially developed by Hutchins and his colleagues in the late 1980s and proposed as a radically new paradigm for rethinking all domains of cognition (Hutchins, 1995). It was argued that what was problematic with the classical cognitive science approach was not its conceptual framework *per se,* but its exclusive focus on modeling the cognitive processes that occurred within one individual. Alternatively, Hutchins argued that what was needed was for the same conceptual framework to be applied to a range of cognitive systems, including socio-technical systems at large (i.e., groups of individual agents interacting with each other in a particular environment).

Part of the rationale for this extension was that, firstly, it was assumed to be easier and more accurate to determine the processes and properties of an "external" system — since they can arguably, to a large extent, be observed directly in ways not possible inside a person's head — and, secondly, they may actually be different and thus unable to be reduced to the cognitive properties of an individual. To reveal the properties and processes of a cognitive system requires doing an ethnographic field study of the setting and paying close attention to the activities of people and their interactions with material media (Hutchins, 1995). These are conceptualized in terms of "internal and external representational structures" (Hutchins, 1995, p135). It also involves examining how information is propagated through different media in the bounded cognitive system.

Distributed Cognition in a Nutshell

The distributed cognition approach provides an event-driven description of the information and its propagation through a cognitive system. The cognitive system might be one person's use of a computational tool, such as a calculator; two people's joint activities when designing the layout for the front page of a newspaper, using a shared authoring tool, or more widely, a large team of software developers and programmers, examining how they coordinate their work with one another, using a variety of mediating artifacts, such as schedules, clocks, to-do lists and shared files.

The granularity of analysis varies depending on the activities and cognitive system being observed and the research or design questions being asked. For example, if the goal is to examine how a team of pilots fly a plane — with a view to improving communication between them — then the focus will be on the interactions and communications that take place between them and their instruments, at a fine level of granularity. If the goal is to understand how pilots learn how to fly — with a view to developing new training materials — then the focus will be at a coarser grain of analysis, taking into account the cultural, historical, and learning aspects involved in becoming a pilot.

The description produced may cover a period of a day, an hour or only minutes, depending on the study's focus. For the longer periods, verbal descriptions are primarily used. For the shorter periods, micro-level analyses of the cognitive processes are meticulously plotted using diagrammatic forms and other graphical representations. The rationale for performing the finer levels of analysis is to reveal practices and discrepancies that would go unnoticed using coarser grains of analysis, but which reveal themselves as critical to the work activity.

A distributed cognition analysis typically involves examining:

- The distributed problem-solving that takes place (including the way people work together to solve a problem).
- The role of verbal and non-verbal behavior (including what is said, what is implied by glances, winks, etc. and what is not said).
- The various coordinating mechanisms that are used, e.g., rules, procedures.
- The various ways communication takes place as the collaborative activity progresses.

- How knowledge is shared and accessed.

It should be stressed that there isn't one single way of doing a distributed cognition analysis. Within work settings, data is collected and then analyzed and interpreted in terms of work practices, routines and procedures followed, and the work arounds that teams develop when coping with the various demands placed upon them at different times during their work. Breakdowns, incidents or unusual happenings are highlighted, especially where it is discovered that excessive time is being spent doing something, errors were made using a system, or a piece of information was passed on incorrectly to someone else or misheard.

Problems can also be described in terms of the communication pathways that are being hindered or the breakdowns arising due to information not propagating effectively from one representational state to another. This level of analysis can reveal where information is being distorted, resulting in poor communication or inefficiency. Conversely, it can show when different technologies and the representations displayed via them are effective at mediating certain work activities and how well they are coordinated.

Hutchins emphasizes that an important part of doing a distributed cognition analysis is to have a deep understanding of the work domain that is being studied. He recommends, where possible, that the investigators learn the trade under study. This can take a team of researchers several months and even years to accomplish and in most cases this is impractical for a research or design team to do. Alternatively, it is possible to spend a few weeks immersed in the culture and setting of a specific team to learn enough about the organization and its work practices to conduct a focused analysis of a particular cognitive system.

The distributed cognition approach has been used primarily by researchers to analyze a variety of cognitive systems, including airline cockpits (Hutchins and Klausen, 1996; Hutchins and Palen, 1997), air traffic control (Halverson, 1995), call centers (Ackerman and Halverson, 1998), software teams (Flor and Hutchins, 1992), control systems (Garbis and Waern, 1999), emergency rooms (Artman and Waern, 1999), emergency medical dispatch (Furniss and Blandford, 2006) and engineering practice (Rogers, 1993, 1994). One of the main outcomes of the distributed cognition approach is an explication of the complex interdependencies between people and artifacts in their work activities. An important part of the analysis is identifying the problems, breakdowns and the distributed problem-solving processes that emerge to deal with them. In so doing, it provides multi-level accounts, weaving together "the data, the actions, the interpretations (from the analyst), and the ethnographic grounding as they are needed" (Hutchins and Klausen, 1996, p19). For example, Hutchins' account of ship navigation provides several interdependent levels of explanation, including how navigation is performed by a team on the bridge of a ship; what and how navigational tools are used, how information about the position of the ship is propagated and transformed through the different media and the tools that are used.

As a theoretical approach, it has received considerable attention from researchers in the cognitive and social sciences, most being very favorable. However, there have been criticisms of the approach, mainly as a continuation of an ongoing objection to cognitive science as a valid field of study and, in particular, the very notion of cognition (e.g., Button, 1997). In terms of its application in HCI, Nardi (1996, 2002) has voiced her concerns about its utility in HCI. Her main criticism stems from the need to do extensive fieldwork before being able to come to any conclusions or design decisions for a given work setting. Furthermore, she points out that there is not a set of interlinked concepts that can be readily used to pull things out from the data. In this sense, Nardi has a point: the distributed cognition approach is difficult to apply, since there is not a set of explicit features to be looking for, nor is there a check-list or recipe that can be easily followed when doing the analysis. It requires a high level of skill to move between different levels of analysis, to be able to dovetail between the detail and the abstract. As such it can never be viewed as a "quick and dirty" prescriptive method. The emphasis on doing (and interpreting) ethnographic fieldwork to understand a domain means that at the very least, considerable time, effort and skill is required to carry out an analysis.

Where the distributed cognition framework can be usefully applied to design concerns, is in providing a detailed level of analysis which can provide several pointers as to how to change a design (especially forms of representation) to improve user performance, or, more generally, a work practice. For example, Halverson (2002) discusses how in carrying out a detailed level of analysis of the representational states and processes involved at a call center, she was, firstly, able to identify why there were problems of coordination and, secondly, determine how the media used could be altered to change the representational states to be more optimal. Hence, design solutions can start to emerge from a detailed level of analysis because the nature of the descriptions of the cognitive system is at the same level as the proposed design. In other words, the low-level nature of a distributed cognition analysis can be most useful at revealing the necessary information to know how to change a design, when it has been identified as being problematic.

There have also been various efforts to develop more applied distributed cognition methods that are more accessible and easier to apply. One in particular that has been used by a number of researchers is Distributed Cognition for Teamwork (DiCoT)—essentially a structured approach for analyzing work systems and teamwork (Blandford and Furniss, 2005; Furniss and Blandford, 2010). The approach draws on core ideas from DC theory and combines them with more practical aspects of contextual design (Beyer and Holtzblatt, 1998; Holtzblatt and Jones, 1993), that resulted in a comprehensive set of underlying themes and principles intended to guide researchers in knowing what to focus on when analyzing and interpreting data from workplace settings. Themes include physical layout, information flow, and the design and use of artifacts; principles include subtle bodily supports (for example, pointing on a screen while replying to someone who walks in and asks a question is part of the mechanism of remembering where they are in a task) and arrangement of equipment (e.g., where computers, printers, etc., are in an office determines who has access to and can interact with information). The themes and principles are intended to help researchers organize their field observations into a set of interdependent models that can help elicit insights about user behavior.

Contextual design

Contextual design (Beyer and Holtzblatt, 1998) is not a theory but an applied approach that was developed to deal with the collection and interpretation of ethnographic findings. It is only briefly mentioned here because it was an important component in the development of the applied DiCoT framework. It is concerned with explicating context and the social aspects of user-interaction and how to use this to inform the design of software. It focuses on how to progress layers of abstractions rather than bridging analysis and design through examining the detail of each. It is also much more prescriptive, promoting a process of transforming data into a set of abstractions and models. The outcome is a very hands-on method of applying research findings, that has proven to be highly successful, with many other practitioners having adopted and used it. Part of its attraction lies in its conceptual scaffolding; it offers a step-by-step approach with various forms to fill in and use to transform findings into more formal structures.

A benefit of bringing together the various strands of the DC literature is to provide a more structured framework that can help researchers and developers to identify the strengths and limitations of the current artifact designs. In so doing, it should enable them to reason systematically about how to re-design the work settings, in terms of considering new technologies, work practices, physical layout, etc. Others have also started to use it to analyze work practices, including software team interactions (Sharp and Robinson, 2008) and mobile healthcare settings (McKnight and Doherty, 2008).

What impact has the distributed cognition approach had on HCI?

The distributed cognition approach has been widely used in HCI to analyze existing practices and to inform new and redesigns by examining how the form and variety of media in which information is currently represented might be transformed and what might be the consequences of this for a work practice. Partially in response to the criticism leveled at the difficulty of applying the distributed cognition approach, Hutchins and his colleagues (Hollan et al., 2000) set an agenda for how it could be used more widely within the context of HCI. They proposed it was well suited both to understanding the complex networked world of information and computer-mediated interactions and for informing the design of digital work materials and collaborative work places. They suggested a comprehensive methodological framework for achieving this.

Conducting a detailed distributed cognition analysis and using the DiCoT method has enabled researchers and designers to explore the trade-offs and likely outcomes of potential solutions and in so doing suggest a set of requirements grounded in the details of the work place, e.g., types of information resources, that are considered suitable for specific kinds of activities. The way theory has been applied from the DC approach has been largely descriptive and, to a lesser extent, generative; providing a detailed articulation of a cognitive system, and in so doing, providing the basis from which to generate design solutions.

5.3 ECOLOGICAL PSYCHOLOGY

The ecological psychology approach — originally developed by Gibson (1966, 1979) — was also considered by several researchers to be more relevant to HCI than the classical cognitive theories, especially for addressing how users interacted with the external world. For Bill Gaver (2008), reading Gibson was a revelation; making a huge impact on his thinking and convincing him of the importance of *contextualizing* human computer interactions in the environment they occur in rather than following the mainstream cognitive approach of isolating and identifying representations solely in the head.

Gibson's view was that psychology should be the study of the interaction between humans and their environment. This involved describing in detail the environment and people's ordinary activities within it (Neisser, 1985). HCI researchers took his philosophy and insights to heart, adapting his concepts in order to examine how people interacted with technological artifacts (Gaver, 1991; Kirsh, 2001; Norman, 1988; Rasmussen and Rouse, 1981; Vicente, 1995; Woods, 1995).

Ecological Psychology in a Nutshell

A central part of Gibson's ecological psychology theory is the notion of invariant structures in the environment and how they relate to human perception and action. Two that were considered most relevant to HCI were *ecological constraints* and *affordances*. Ecological constraints refer to structures in the external world that guide people's actions rather than those that are determined by internal cognitive processes. An affordance refers to the relationship between the properties of a person and the perceptual properties of an object in the environment. Within the context of HCI, it is used to refer to attributes of objects that allow people to know how to use them. In a nutshell, to afford is taken to mean "to give a clue" (Norman, 1988). Specifically, when the affordances of an object are perceptually obvious it is assumed that they make it easy to know how to interact with the object (e.g., door handles afford pulling, cup handles afford grasping). Norman (1988) provided a range of examples of affordances associated with everyday objects such as doors and switches — that were easy to understand and use when talking about interfaces.

This explication of affordances in HCI is simpler than Gibson's original idea — and to some extent that has been part of its appeal. It rapidly came into widespread use in HCI providing a way for researchers and designers, alike, to describe interfaces, suggesting to the user what to do when carrying out a task. It provided them with an easy to use shared articulatory device, helping them think about how to represent objects at the interface that could readily afford permissible actions (Gaver, 1991) and providing cues as to how to interact with interface objects more easily and efficiently.

It is not necessary to know about the original ecological psychology theory to understand the concepts that have been imported into HCI. Instead, the idea of invariant structures is taken as a given. The problem of only having a shallow understanding of an affordance, however, is that it requires working out what are affordable objects at the interface (St. Amant, 1999). There are no abstractions, methods, rules or guidelines to help the researcher identify instances of something — only analogies drawn from the real world.

Indeed, many designers began to use the term affordances to apply to everything, and as a way of thinking and talking about what adding a feature to the interface might mean to the user. It became easy to slip into talking about the meaning of an icon, the way a scroll bar moved, and the positioning of a window — as being easy to understand, because they afforded clicking on. Norman, however, was horrified at how sloppily the term had become used in common design parlance. To better articulate how to use the notion of affordances at the interface, he thought it important to understand the distinction between two kinds: perceived and real (Norman, 1999). On the one hand, physical objects were considered to have real affordances, as described above, like grasping, which are perceptually obvious and do not have to be learned. User interfaces that are screen-based, on the other hand, do not have these kinds of real affordances. Importantly, this means that users have to learn the meaning and function of each object represented at the interface before knowing how to act. Norman argued that screen-based interfaces have perceived affordances, which are based on learned conventions and feedback. For example, having a red flashing button icon appear at the interface may provide visual cues to enable the user to perceive that clicking on that icon is a meaningful useful action at that given time in their interaction with the system, that has a known outcome.

Vicente (1995) and Vicente and Rasmussen's (1990) considered it more beneficial to import more of the original theory into HCI, and so developed the Ecological Interface Design framework. Affordances were described in terms of a number of actions (e.g., moving, cutting, throwing, carrying). The various actions are sorted into a hierarchy of categories, based on what, why and how they afford. The framework was intended to allow designers to analyze a system at different levels, which correspond to the levels in the hierarchy.

Kirsh (2001) also proposed operationalizing the notion of affordance by grounding it more in the original Gibsonian ideas. Instead of couching it in terms of objects giving clues as to what to do, he proposed viewing affordance in terms of structures in the environment that *invite* people to do something. The term he used was *entry points*. Consider the way information is laid out on posters, websites and magazines; they provide different entry points for scanning, reading and following. These include headlines, columns, pictures, cartoons, figures, tables and icons. Well-designed information allows a person's attention to move rapidly from entry point to entry point for different sections (e.g., menu options, lists, descriptions). Poorly designed information does not have clear entry points — it is hard to find things. In Kirsh's terms, entry points are affordances in the sense of inviting people to carry out an activity (e.g., read it, scan it, look at it, listen to it, click on it). This reconceptualization potentially has more design purchase as it encourages designers to think about the coordination and sequencing of actions and the kind of feedback to provide, in relation to how objects are positioned and structured at an interface — rather than simply whether an object *per se* suggests what to do with them.

The concept of entry points has since been used successfully in interaction design as a design and conceptual tool. For example, Lidwell et al. (2006) have operationalized it as a generative design principle, describing features that, on the one hand, lure people into them and, on the other, do not deter them from entering them. Rogers et al. (2009) used entry points as the basis of their Shared Information Spaces framework, which was intended for researchers to think about how to constrain or invite group participation and collaboration through the layout of a physical room, the display and device interfaces provided and the kind and way information is presented (physical or digital). The assumption is that the design of entry points can provide different ways for participants to collaborate in both verbal and physical modes that lend themselves to more or less equitable participation. Hornecker et al. (2007) have also incorporated entry points into their comprehensive framework on the shareability of devices. The framework also includes other concepts such as access points, overview and fluidity of sharing, which are intended to show the relationship between elements of space, technology and people, by denoting design characteristics that invite people into engagement with a group activity and entice them to interact and join a group's activity. The assumption is that considering the relationship between the various elements in the framework can encourage a more comparative approach to designing interfaces for shared use. In so doing, it can enable a number of more specific research questions and hypotheses to be generated that could be investigated experimentally.