DEVELOPING AN ORGANIZATIONAL MODEL FOR INTUITIVE DESIGN

Technical Report HFA-TR-1001
Atlanta, GA: Georgia Institute of Technology
School of Psychology – Human Factors and Aging Laboratory
2010

MARITA A. O'BRIEN
WENDY A. ROGERS
ARTHUR D. FISK

Requests for more information may be sent to Wendy A. Rogers, School of Psychology, Georgia Institute of Technology, Atlanta, GA 30332-0170 (electronic mail to wr43@mail.gatech.edu).

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The construct of intuitive design is a prevalent point of discussion in the context of system design but it is a poorly understood construct with definitions varying across and within companies producing products. Many systems are based on the concept of analogy – for example, organize a system like a book to support a user's ability to find information. An open question is how performance knowledge that has become "intuitive" because of experience transfers across systems, across contexts, and across products.

Marketing descriptions of many high technologies indicate that intuitive interactions are an attractive but an elusive characteristic of the target experience with these products and systems. The ambiguity of the definition makes it challenging for technology designers to create products that facilitate this experience.

We need to create a measurable outcome to determine if something is intuitive or not. We need to understand the variables that relate to intuitive design, and we need to understand how prior knowledge enables a user to interact with a so-called intuitively designed system (or interferes with use of that system). What is required first is a thorough analysis of variables that relate to intuitive design. This analysis will enable the development of operational definitions to assess objectively what makes something intuitive to use and what constrains intuitive use.

This report provides an overview of our initial efforts to develop a guiding framework for the concept of intuitive design with sufficient specificity to allow designers to meet the marketing goal. We first conducted an in-depth review of research on intuition in general psychology, educational and management psychology, decision-making, cognitive engineering, and neuroscience literatures to develop a top-down perspective. We identified 17 characteristic attributes of intuition to be considered for inclusion in the framework.

The next step was to evaluate research describing how novice users interact with high technology after only minimal training to better understand natural use of prior experience to achieve

goals with a new system. By comparing this bottom-up perspective with the 17 attributes originally identified, we determined that intuitive attributes supporting general ease of use were manifested in novice interactions but that designs were still limited in protecting users against serious error and frustration and in eliciting changed behavior. We also examined human-computer interaction (HCI) guidelines and design research to identify knowledge gaps and other attributes that might be essential for intuitive interactions in HCI.

These complementary reviews resulted in an organizational framework for intuitive design comprised of six components:

1. seeking user goals
2. performing well-learned behavior
3. determining what to do next
4. metacognition
5. knowledge in the head
6. knowledge in the world

We also propose a working definition for intuitive design: *interactions between humans and high technology in lenient learning environments that allow the human to use a combination of prior experience and feedforward methods to achieve their functional and abstract goals*. From these high-level concepts, we developed three tools to help developers create intuitive high technology: workflows, specific requirement guidelines, and evaluation techniques.

Further research is required to validate the organizational framework and the tools as effective means to guide development. Our current research focus is on investigating the role of prior experience in interactions with novel technologies as this seems to be a dominant factor in the determination of whether something seems “intuitive” to use.

CHAPTER 1: INTRODUCTION

Defining "Intuitive" Use

The term 'intuitive" is frequently used in advertisements for high technology as a marketing tool to attract buyers to new products:

- "Oracle Application Server makes it easy… in an organized and *intuitive* way"
- "The HP MFPs … have a powerful combination of features … including *intuitive* usability…"
- "Mobile VoIP through one highly *intuitive*, easy-to-use interface…"
- "the Megadyne medical product's *intuitive* design and easy set-up allows your surgical team to hit the ground…"
- "Ava-Tex is a system of components engineered to be *intuitive* to the specialist's needs…"
- "MyDesignIn is an innovative, eye-catching, *intuitive* application that…"
- "Appreciate how easy it is to save time and money with this *intuitive* and well-designed program…"
- "The iPod interface is also simple and *intuitive…*"

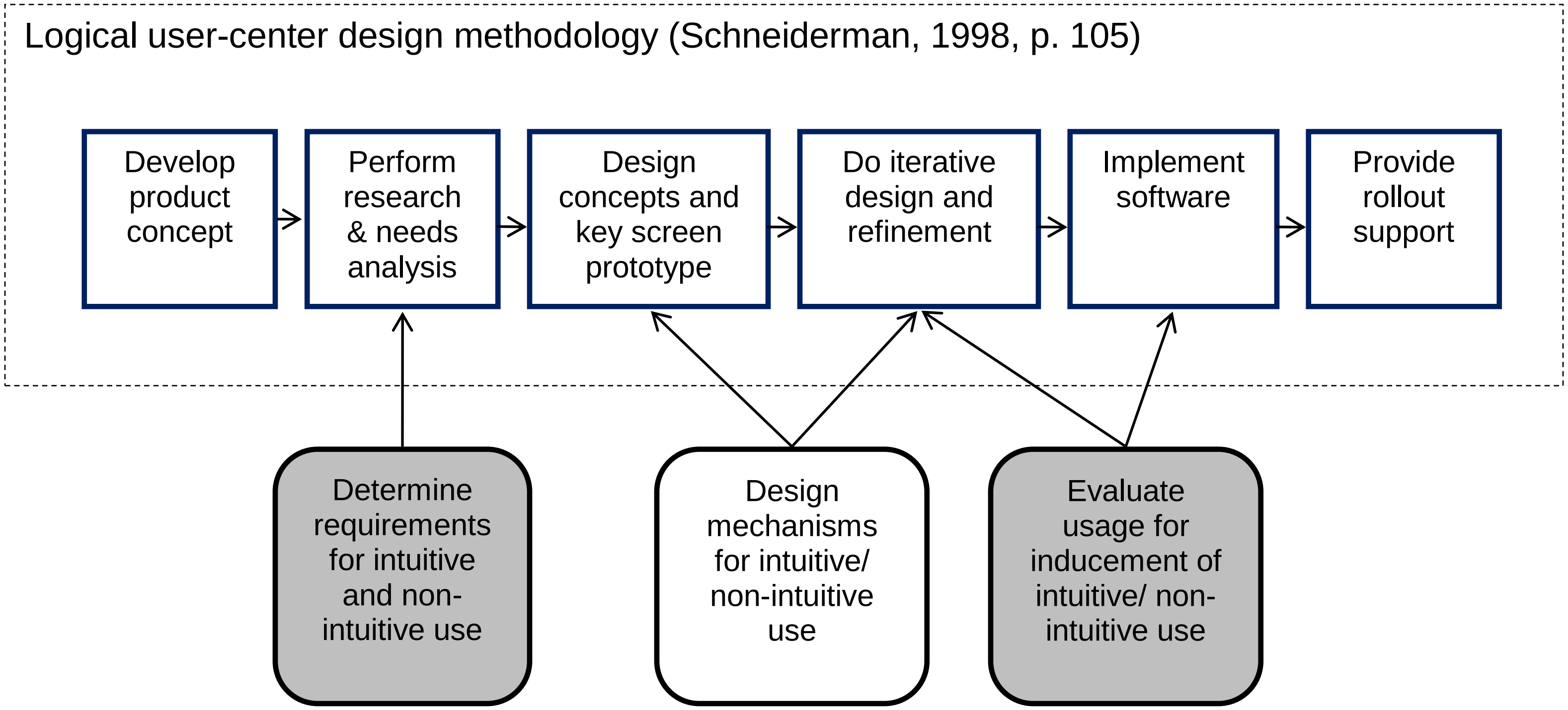
These examples illustrated representative uses of intuitive in different domains. The use of intuitive as praise for new devices that "work the way a user does…using normal human cognition with no additional thought or training" (Raskin, 1994, p. 17) is not new, but was criticized over a decade ago for the same reasons it is often criticized now. The implication is that users will be attracted to a product and find it easy to use, but the exact attributes of the product that make it intuitive are elusive. Although this ambiguity may not be a concern in the context of marketing as a mechanism for inviting users to experience the product for themselves, the ambiguity does present a challenge for designers, computer programmers, and systems analysts to deliver the product and interaction described by the advertisement.

Design and computer professionals find little assistance in meeting this challenge from human-computer interaction (HCI) manuals (e.g., Mayhew, 1999; Nielsen, 1994) or engineering psychology textbooks (e.g., Salvendy, 1997; Wickens, Gordon, & Liu, 1998). Perhaps not surprisingly, neither intuitive nor its derivatives (i.e., intuition) are in the indexes of these texts. Instead, professionals have used guidelines from these references for designing "usable" interactions.

The target of usable interactions is consistent with suggestions from computer (Raskin, 1994) and design (Cooper, 1995) commentators that intuitive means familiar, easy to use, or easy to understand. Yet, replacing the term intuitive with these synonyms in the example quotations demonstrates that these definitions are inadequate. In fact, Internet and HCI design pioneer, Douglas Englebart, has been quoted as saying, “If ease of use was the only valid criterion [for technology], people would stick to tricycles and never try bicycles” (Beale, 2007, p. 21). Good technology should not only support users in their current abilities, but it should also foster new abilities through discovery and experimentation.

The goal of this report is to provide an overview of the relevant research on the topic of intuitive design; to develop an organizational framework for that literature; and to propose a formal definition and framework for intuitive interaction that will provide a basis for identification, evaluation, and measurement of this behavior in system design and evaluations.

As shown in Figure 1, an understanding of intuitive interactions can impact standard user-centered design in three ways. First, the designer must identify the need for intuitive and non-intuitive use within the research and needs analysis. One product of the current review will be support for such identification with guidance to determine the appropriate contexts, environments, and populations for which intuitive interaction is appropriate and inappropriate. Second, the designer must design stimuli, action selections, controls, etc. that elicit target usage. We present high-level guidance characteristics of intuitive/non-intuitive designs that might be considered as part of initial design concepts; however specific mechanisms are beyond the current scope. Third, the designer and usability analysts must evaluate whether the designs



Note. The three bottom-most boxes indicate where an understanding of intuitive interaction can influence user-centric design. The present report is targeted at specifying requirements and measurement approaches in the two shaded boxes but the resulting framework will also influence the center box.

Figure 1. Role of understanding intuitive interaction in user-centric design.

actually induce the target usage in the target scenarios. We propose measurement approaches for this evaluation. Overall, designers should understand the mechanisms and attributes of intuitive interaction well enough to reduce guesswork about how users might interpret their products and systems.

Evaluation Approach

Our approach for developing this framework was to review research on intuitive behavior in general and with high technology in particular. First, an in-depth literature review systematically examined research on intuition and intuitive behavior in the psychology, management science, and cognitive engineering domains to identify definitions and attributes of humans' capacity and use of intuition. This research particularly focused on use of intuition in decision-making, based on the observation that the user's selection of an action is a decision. This assessment yielded an initial set of relevant design attributes.

Second, we examined two HCI research areas to inform the understanding of how computer design influences human interactions: how average users behave when encountering desktop computers and the Internet; and guidelines and design best practices for HCI selected to induce effective system use. For both these research areas, comparisons were then made to the design attributes identified in the general literature review to assess similarities and differences. All attributes determined to be important for intuitive interaction were incorporated into a framework with each component defined with respect to its role in intuitive interaction.

The third step was to assess the inclusiveness and flexibility of the initial framework with respect to other relevant psychological and HCI research.

Scope of Assessment

We investigated intuitive HCI within four constraints:

(1) Focus on high-technology, defined as "technology that involves highly advanced or

specialized systems or devices" (American Heritage College Dictionary, 1993).

(2) Focus on interactive behavior between humans and high technology, as defined in Byrne, Kirlik, and Fick (2006, p. 270) to have three main components: a) embodied cognition ("capabilities and limitations of the integrated human-perceptual-cognitive-motor system"); b) environment ("constraints and affordances available to humans in the environment…including the high technology itself"); and c) task ("set of goals that the user is trying to accomplish…[and the] knowledge required to fulfill these goals").

(3) Focus on novices who are new to the specific high technology being considered. Specific characteristics of these users are likely to include: a) users have incomplete information about the system when they use it; and b) users may be guided by limited motivation to learn the system and limited patience in using the system.

(4) Focus on requirements and evaluation approaches as opposed to recommending specific design features of intuitive technologies. As shown in Figure 1, the focus areas are the shaded gray boxes.

CHAPTER 2: LITERATURE REVIEW ON INTUITION

The first goal for developing the construct of intuitive interaction was to describe this behavior so that we can identify characteristic attributes of the behavior. We start with the dictionary definitions of intuition which may best represent the meanings ascribed to the term in marketing communications. We then describe a systematic literature review of intuition in psychology, management science, and cognitive engineering. We first review early empirical studies of intuition that investigated methods of measuring intuition and characterizing intuitive cognition vs. non-intuitive cognition. We then discuss six research areas that have elaborated on the construct by investigating specific aspects of intuitive behavior.

Definitions of Intuition

A typical lay definition of intuition comes from the 3rd Edition of the American Heritage College Dictionary (1993).

> *1a The act or faculty of knowing or sensing without the use of rational process; immediate cognition;*
> *1b Knowledge gained by the use of this faculty; a perceptive insight;*
> *A sense of something not evident or deducible; an impression.*

The definitions used in the research literature are much more disparate. Appendix A presents 65 specific or implied definitions of intuition and its derivatives (i.e., intuitive, intuitively) selected from 41 different sources to illustrate the variety of meanings ascribed to the term. One of our goals is to develop an integrative definition that reflects the research literature.

Early Empirical Studies

We identified 112 attributes in the literature review to describe intuition which we grouped into 17 broad categories. Interestingly, 16 of these categories were identified in the early research studies on intuition by Bouthilet (1948) and Westcott (1961, 1968).

Bouthilet's (1948) dissertation on the measurement of intuitive thinking was derived from philosophical and early psychological speculation on a cognitive capacity that allowed humans to quickly know information without awareness of processing stimuli or using a rational approach to achieving the answer. Because she hypothesized that this capacity was similar to the use of insight in problem-solving, she based her experimental techniques on previous insight studies. Participants were asked to memorize 20 paired words; the word pairs were in fact not random but based on a strategy in which the pair was devised by using a subset of the letters in the first word to create the second word (e.g., participate-tear). Two thirds of the participants discover the correct strategy but only half of these participants demonstrated awareness and could verbalize the strategy. Bouthilet's findings suggested nine attributes of intuition:

1) *Quick, immediate, sudden appearance* of intuition that feels like a percept;
2) In spite of this feeling of immediacy, *antecedents* to the intuition can be identified that provide evidence that the participant is orienting to the problem and solution;
3) *Confidence in solution* and feeling of importance that guides usage of the insight and orientation
4) *Emotional involvement* and use of feelings to guide the participant's orientation and exploration of the problem and possible solutions
5) *Participant's search for coherence/Gestalt* and sense of relations reported by participants because of clear lack of time to memorize pairs. Some participants used the words *harmony* or *beauty* to describe their search target;
6) Use of *recentering* in which participants stopped thinking of the task as a memorization task and tried to discover other possible strategies supporting the time-limited nature of the task;
7) Participants realized they *need not be correct* in their responses as there was no penalty for guessing incorrectly. This allowed participants to form a hypothesis on the relationship between items and test the hypothesis with their guesses;
8) *Preconscious process* for discriminating and using the intuition such that 1/3 of the participants were not able to verbalize a strategy that they appeared to use, even when asked afterwards about the strategy.
9) *Use of prior experience* as no participants discovered the strategy in the first block of trials. The evidence of complete preconscious awareness of the solution for some individuals and identification of precursors in response trends for other individuals suggests that participants used implicit learning techniques to find the solution.

Although Bouthilet's (1948) participants developed the intuition at different points during the experiment with the same information, Westscott (1961) examined participants' usage and requests for different levels of information to support intuition development. In his study participants completed verbal and numerical series and analogies using no more than five clues to provide the correct response. Clues were revealed one at a time, but participants were allowed to guess the correct response when they felt that they had sufficient information. Participants' confidence in their solution was clearly related to their success of solving problems and there was a significant positive correlation between confidence and efficiency and solving problems. Problem-solvers could be divided into four groups: steady problem solvers, poor problem solvers, wild guessers, and successful intuitive thinkers. Differences in these groups were based on differences in their consistent use of confidence, solution correctness, solution efficiency and the interaction of these variables. Steady problem solvers had consistently similar information demand for the same types of problems. Poor problem solvers did not adjust their information demand to their solution confidence. Wild guessers were willing to offer responses even with inconsistent solution confidence but consistently low information demand. Only successful intuitive thinkers adjusted their information demand to solution confidence to achieve high solution efficiency. Generally, Westcott's research confirmed several of Bouthilet's (1948) relevant attributes regarding the use of intuition in problem-solving, but also identified several additional ones:

(10) *Individual differences* of the use of intuition are measurable, fairly stable, and operate within a continuum. Even within individuals attempting to solve a problem similar to one before, though, one may observe a variety of paths followed in gathering information and proposing the solution.

(11) Effective use of intuition requires that individuals develop *expectations* about the result of the next action based on their current hypothesis. If a new clue is consistent with their hypothesis, confidence increases and the individual may offer the problem solution. If the clue is inconsistent, confidence decreases and the individual should mentally review prior clues and previous knowledge to alter the hypothesis.

(12) In attempting these types of problems, individuals expect that their *knowledge is incomplete* but by filling in the information gap they can increase their confidence in a hypothesized solution. They do this by recognizing that some clues are not useful in a particular context or that some clues should be weighted more heavily than others. They may also use rapid categorization to fill in missing information.

These conclusions were refined and organized into a general two stage model for intuitive ability in Westcott (1968). In the first stage, participants gather information to orient them to the problem based on current environment, context, and prior knowledge. They continue to gather information until the information is synthesized in the second stage. A test of this model yielded similar results to the 1961 study with an additional identification of the individual preferences for responding early or late. Overall, individual differences in intuitive tendencies and previous knowledge (particularly global knowledge) seem to affect the usefulness of the clues offered as stimuli. The method of utilizing information demand and confidence to measure use of intuition was formalized into The Test of Intuitive Ability which proved to be reliable measure.

The Westcott (1968) review also highlighted four other characteristics of intuitive behavior that had not been discussed in previous research:

(13) The *type of cues* affects individuals' use of intuitive cognition in several ways. When the information is complex, absent, or limited and individuals have limited time for to manipulate the information to make it easier to process, he suggested that they are likely to use intuitive cognition. The presentation format of the cues also affects intuitive use to the extent that the cue salience and organization are easily perceived, generating a feeling of concreteness that supports the sense of immediacy that helps elicit intuitive behavior.
(14) *Low cognitive effort* is applied to intuitive cognition, which Westcott suggested was expected due to his view that intuitive cognition operates as quickly and easily as patterned perception.
(15) *Dependence on the environment*, including understanding the task and stimulus conditions, allows the human to efficiently use the offered information.
(16) Relaxed attitude with dispersed *focus of attention* allows the human to access peripheral clues that may provide redundancy for recognizing a particular pattern.

In summary, these early studies yielded 16 characteristics of intuition that might facilitate identification and measurement of the use of intuition, though these studies provided limited evidence of whether any of these characteristics are necessary and sufficient for intuition to operate.

We turn next to six research domains wherein studies relevant to intuition have been conducted: educational psychology, general decision-making, management decision-making, naturalistic decision-making, cognitive engineering, and neuroscience. This research review allowed us to elaborate on the characteristics identified in the initial research studies and to define one additional characteristic formally addressed beyond these first studies, that of contrasting intuition with an analytic mode of thinking.

Intuition in Education Research

Intuition has been investigated in the context of education because of the potential for this cognitive process to facilitate better student learning. Beginning in the early 1980s when this research by Simonton (1980) and Bastick (1982) was completed, an evolving role was seen for educators "as facilitators, not just instructors, to organize information and the environment to allow people to explore and comprehend information in their own manner" (Davis-Floyd & Arvidson, 1997, p. xiii). Thus, educational psychology could particularly expand the prior research from investigating intuition's role in simple problem-solving to examining how intuition might help facilitate more complex and novel problem-solving. This research could also promote understanding individual differences in exploring and comprehending information.

Simonton (1980) proposed a predictive and explanatory model for the use of intuition and its complement, analysis, in learning and problem-solving. These modes of cognition are viewed as the two ends of a continuum that are rarely completely engaged but often used in combination through a quasi-rational approach. His primary contributions to the investigation of intuition were propositions about when each mode is most effective, how different types of associative networks elicit different cognitive modes and how individual preferences for processing modes are based on a greater supply of processing operations particularly effective for that preference:

> *Proposition 1*: The analytic mode is necessary for learning deterministic relationships between stimuli and events such as used in engineering problems but the intuitive mode may be better for learning probabilistic relationships.
>
> *Proposition 2*: Physical, emotional, and connotative relationships among concepts elicit intuitive processing but denotative and syntactical relationships among concepts elicit analytical processing. Use of aesthetics in selecting and organizing stimuli presentation promotes intuitive use of emotional connections to generate novel ideas and approaches.
>
> *Proposition 3*: "an analytical person enjoys a richer supply of alternative hypotheses, formal operations and problem-solving strategies" than the intuitive person with a "richer supply of infraconscious associations for intuitive scanning and experimentation" (Simonton, p. 45).

Together, these propositions suggest that a systematic understanding of the problems presented to the learner is the first step in designing effective support for problem-solving. This understanding may also be relevant for proposing requirements for intuitive systems.

Individual differences in exploring and comprehending information may be understood by investigating individual differences in motivation and emotion. Bastick's (1982) Theory of Intuitive Thought was based on the proposal that all information is emotionally coded by humans and can therefore be linked through these associations in emotional sets that complement other types of associative networks. Intuition thus allows preconscious examination of the level of activation of combinations of emotional sets to determine if the level is greater than some predetermined level of execution that selects behavior. This view also suggests that individuals can allow their feelings to direct a subconscious search for an answer through the use of "hypnogogic reverie" (dreaming) and transfer/transposition of different cues until a harmonious pattern is identified and the activation level becomes greater than the level of execution. Similar to Simonton's (1980) proposition that scanning for patterns and support for a particular pattern is characteristic of intuition then, Bastick's proposal also suggests a way that individuals can solve a problem in which the goal state is not well known as might be expected in novel problems or known problems in new environments or contexts.

Use of this intuitive mode, however, is based on characteristics suggested by early researchers. An acceptance of error and use of hunches, guesses, and vague cues to develop the answer is crucial to supporting the subconscious scanning. In addition, the feeling that guides exploration of options is similar to the subjective feeling of confidence discussed earlier. Bastick (1982) added that the positive affect generated by a correct answer or correct hunch even along the path to the solution may serve as conditional reinforcement to the intuitive behavior. Redundant coding of items and the task environment also facilitates idiosyncratic approaches and associations that characterize the non-linear nature of this exploration. Bastick suggested, though, that individuals provide some control over the exploration by using existing stories and experiences as potential patterns of coherence to identify and synthesize data in the current problem space. He also provided evidence for Westcott's (1968) suggestion of the importance of peripheral cues by citing Daniels'

(1973) dissertation that used the Test of Intuitive Ability to show that stress reduced the perception of cues and consequently the use of intuitive thinking.   Bastick's research thus advanced the understanding of characteristics important to intuition and suggested why emotion may be particularly important in facilitating intuition in novel environments. In addition, individual differences in experience and use of emotion may also explain differential access and associations to knowledge that may guide intuitive interactions.

Intuition in General Decision-Making Research

Research on decision-making has its origins in Brunswik's theory of visual perception (1943, cited in Hammond, 1996a). According to this theory, humans only have probabilistic access to the distal environment but the cognitive system can nonetheless generate good decisions if proximal cues provide accurate information about the distal cues and the environment is representatively sampled. The idea is that the presentation and usage of cues along with a probabilistic relationship between cues can elicit intuitive thinking. An additional variable to consider is the degree to which the decision-making task is dynamic (as opposed to static) wherein the stimuli and actions available at time t depend on the responses chosen at time $(t-1)$. Both the probabilistic and dynamic characteristics of these activities make prediction of cognitive mode more difficult, but understanding the impacts at each end of the continuum could facilitate more appropriate design.

An important study in this area was Hammond, Hamm, Grassia, and Pearson's (1987) systematic investigation of whether task elements (including the stimuli) influenced the cognitive mode participants selected to complete a task. In this study, highway engineers made judgments that were expected to be characteristic of different cognitive modes: aesthetics, safety, and capacity. Different stimuli were used to try to induce each task mode: film strips of highway sections for intuitive judgments, bar graphs for quasi-rational judgments, and paper, pencil, calculators, and sufficient time for inducing analytic judgments. These task modes were selected based on the proposed model for intuition-inducing vs. analytic-inducing characteristics (see Table 1). Note that the display of cues (characteristic 10 in Table 1) is based on a surface view of the variables available to the user vs. a depth view of the variables, which represents the actual functional relationship of the variables and may be only available to the systems analyst or designer.

Table 1. *Inducement of Intuition and Analysis by Task Conditions* (from Hammond et al., 1987, p. 756)

Task characteristic	*Intuition-inducing state of task characteristic*	*Analysis-inducing state of task characteristic*
1. Number of cues	Large (>5)	Small
2. Measurement of cues	Perceptual measurement	Objective, reliable measurement
3. Distribution of cue values	Continuous, highly variable distribution	Unknown distribution; cues are dichotomous; values are discrete
4. Redundancy among cues	High redundancy	Low redundancy
5. Decomposition of task	Low	High
6. Degree of certainty in task	Low certainty	High certainty
7. Relation between cues and criterion	Linear	Nonlinear
8. Weighting of cues in environmental model	Equal	Unequal
9. Availability of organizing principle	Unavailable	Available
10. Display of cues*	Simultaneous display	Sequential display
11. Time period	Brief	Long

** Applicable to surface conditions only.*

Hammond et al. also proposed a cognitive continuum index with characteristics of each pole identified as shown in Table 2. In the study highway engineers provided each judgment on 40 rural highways using a think-aloud protocol, allowing coding of the cognitive activity for each judgment and assignment on the cognitive continuum index (CCI). Measurements of each engineer's accuracy, type of error, confidence in method used for each judgment and confidence in each answer were recorded.

Table 2. *Cognitive Continuum Index for Intuitive and Analytic Ends of the Continuum (Hammond et al., 1987, p. 755).*

	Intuition	*Analysis*
Cognitive control	Low	High
Rate of data processing	Rapid	Slow
Conscious awareness	Low	High
Organizing principle	Weighted average	Task specific
Errors	Normally distributed	Few, but large
Confidence	High confidence in answer; Low confidence in method	Low confidence in answer; High confidence in method

Task properties did induce selection of the most appropriate cognitive mode. In fact, higher correspondence between task properties and cognitive properties was significantly correlated with accuracy of the participant’s judgments. Intuitive and quasi-rational cognition were also found to be as accurate as analytical cognition for some judgments. As expected, analytical cognition was more likely to produce extreme errors (e.g., miscalculation, incorrect application of formula). Hammond et al. (1987) suggested that analysts should estimate the location of the task on the task continuum and maximize the probability of accurate judgments by displaying appropriate task features that induce appropriate cognitive activity. Analysts should also be aware, however, that task context can override display features in eliciting cognitive modes such as when insufficient time induces intuitive judgments and transparency for audit induces analytical cognition. Overall, this research corroborates Simonton's (1980) recommendation that understanding the type of problem the user will be solving is critical to effective system design.

A follow-up study by Hamm (1988) evaluated the use of intuition vs. analytic cognition on a molecular basis rather than at the molar task level examined in Hammond, Hamm, Grassia, and Pearson (1987). Given the results of the prior study in which task components induced the corresponding cognitive mode for effective performance, Hamm wondered whether there were patterns of moment-by-moment performance consistent for each cognitive mode or whether there were consistent patterns of transition and oscillation in any kind of dynamic decision-making environment. Figure 2 shows possible patterns of cognitive mode usage (curves 1-5), which Hamm called the Moment By Moment Cognitive Continuum Index (MBMCCI).

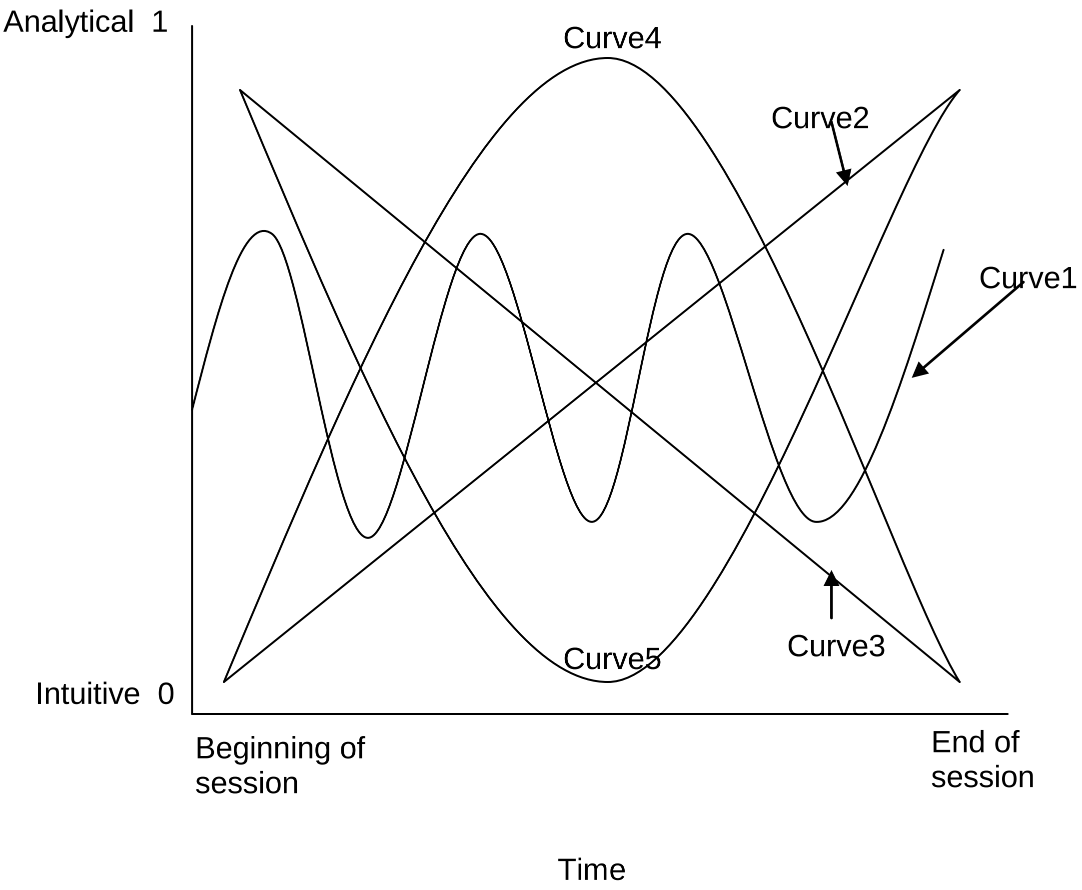


Figure 2. Possible patterns of change in MBMCCI (Moment by Moment Cognitive Continuum Index), from Hamm, 1988, p. 766.

There were significantly fewer shifts of cognitive mode that would have been expected by chance, with the rate of alternation that was expected by stringency of task standards (i.e., more rapid alternation for capacity judgments than aesthetics for which engineers stated that they expected aesthetic judgments to be less rigorous). Overall, though, there was a stronger pattern of analytic/intuitive/analytic (similar to curve 5 in Figure 2) for more than 50% of the tasks, particularly for the aesthetic task. Nonetheless, there was still more analytic cognition in the capacity task than the aesthetics task. A low correlation between mean MBMCCI and CCI was also found across sessions with many instances of rapid alternation between modes. This general pattern was not different by task type. Thus, Hamm did not believe that either index accurately describes the task.

The patterns of alternation also did not reflect pure quasi-rationality with consistent, periodic alterations but instead reveal patterns that reflect accuracy needs and type of task in somewhat surprising ways. For instance, formula accuracy was related to more use of intuitive activities of memory, assignment of causality, and use of quality schemas. Yet, the more an engineer used pure analysis and selected activities from a knowledge schema, the more accurate was the formula. Accuracy was also related to engineers' setting of solution constraints prior to generating a formula, though this was considered an intuitive activity. In fact the more time an engineer spent setting constraints ahead of time in an environment like this one where no feedback was given, the more important it was for the engineer to predict the expected response to a step before taking action. In these cases the expectancies may have induced the engineer not only to predict the effect of the next action but also to predict available actions and stimuli that will then be available.

Further research and reviews by Hammond and colleagues (e.g., Hammond, 1993) and Kahneman, Sloman, and colleagues (e.g., Kahneman & Frederick, 2002; Sloman 1996) refined the concepts of intuitive vs. analytic processing and an update of the Cognitive Continuum Index. The factors of organizing principle, errors, and confidence were replaced by amount of shift across indicators, memory stored, and metaphors used. This replacement suggests recognition that the earlier factors represented feedback that may never reach conscious awareness and may be hard to predict. Later factors also represent attributes that may be predicted based on availability and differences between alternatives, stimuli and mental models suggested by the task and environment.

Several researchers have further specified this idea by suggesting that the intuitive system is the primary default cognitive system (System 1) and that the role of the analytic system (System 2) is to endorse, correct, or override the proposal generated easily by System 1 (Kahneman & Frederick, 2002). Characteristics of these cognitive processes and the types of stimuli on which they operate are presented in Table 3. The main challenges addressed by this research are the unconscious nature of the criteria and the selection process. Humans are continually trying to efficiently understand the world and identify what matters (Sloman, 1996). However, research on cognitive illusions, heuristics, and biases demonstrates many examples of the ways that the intuitive mode (e.g., Tversky & Kahneman, 1971) generates incorrect decisions. With the availability heuristic, for instance, individuals may use easily available cues in an environment to diagnose a situation and determine the course of action even though the cues used are only coincidental and not causal to the situation. In this and similar cases, System 2 should override the decision though it may not if the feeling of familiarity is high and the individual is experiencing positive affect (Kahneman & Frederick; Kahneman 2003). There is also no opportunity for System 2 to intervene or even for System 1 to correctly process cues if these cues are not available as they may be in artificial environments or on computers where displays present only a subset of the potentially relevant cues (Horrey, Wickens, Strauss, Kirlik, & Stewart, 2006). Thus, system designers have an increasing responsibility with technology development to be aware of what kind of cognitive mode they should be inducing and supporting for automated tasks.

Table 3. *Process Characteristics and Content for Two Cognitive Systems* (from Kahneman & Frederick, 2002, p. 51).

System 1(Intuitive)	*System 2 (Reflective)*
Process characteristics	
Automatic	Controlled
Effortless	Effortful
Associative	Deductive
Rapid, parallel	Slow, serial
Process opaque	Self-aware
Skilled action	Rule application
Content on which processes act	
Affective	Neutral
Causal propensities	Statistics
Concrete, specific	Abstract
Prototypes	Sets

Intuition in Management Decision-Making Research

Because many good managers and other professionals have been found to use intuition in their decision-making, management science researchers have developed approaches to studying more complex decision-making. In these investigations, researchers manipulated variables hypothesized to affect intuition and test the results of these manipulations. Early findings in this domain can be found in Hammond’s (1996b) studies on the use of different cognitive modes among medical, legal, and political decision-makers. He found the same type of oscillation between intuitive and analytic modes identified in previous studies from his lab, but he also elaborated on the use of stories and mental simulation by these professionals to investigate particular diagnoses and rulings. These findings support Pennington’s (1993) earlier review of medical and legal decision in which she found that one common decision-making technique by individuals was the construction of a causal model sufficiently complex to facilitate decisions. The technique was not only used by professionals but also by juries making a single decision based on the search for an explanation that was most coherent, unique, and fitting for all available data. These techniques seem to provide decision-makers with sufficient confidence in their results to overcome the challenges of complex environments, incomplete data, and changing contexts, though these confirmatory feelings may be dismissed as an emotion in favor of post hoc analytical explanations (Sinclair & Ashkanasy, 2005).

The role of intuitive confidence was examined specifically in a series of studies by Simmons and Nelson (2006). They hypothesized that individuals experienced beliefs held with certainty as percepts, making them easily accessible and salient for guiding decision-making. They investigated how point spreads, expressing an external confidence in a decision for various sporting events, can be manipulated to affect individuals' judgments on the likely outcome of these games. A subset of the experiments allowed participants to manipulate the point spreads themselves before judging the likely outcome of the games. Overall, results showed that participants overweight outcomes considered certain relative to merely probable outcomes. This result is consistent whether the confidence was externally or internally generated. In addition, decreasing intuitive confidence reduced or eliminated intuitive biases in general. These effects were mediated by contextual effects that independently affect confidence such as the low confidence inspired by a font that was difficult to read. The experimenters concluded that individuals may rely on these metacognitive feelings of confidence as highly relevant cues for decision-making. Thus, systems designers may need to be aware of all factors affect individuals' confidence to structure the tasks and supporting environment for effective execution.

Business executives are also concerned with how to create an environment that fosters accurate decision-making, and a review of this research may provide suggestions that are useful for HCI. As noted in the prior section of this chapter, the two poles of the cognitive continuum are complementary and effective when used correctly. The analytic mode is generally preferred in business environments where transparent decision-making is highly valued. In addition, teams may share information in a complex decision-making task and must ensure that they are interpreting the cues consistently and not using (possibly idiosyncratic) heuristics to fill in missing data (Hammond 1993).

Intuitive processing may be enlisted, however, due to time constraints, incomplete data, novel contexts, etc. Researchers have begun to investigate methods of educating professionals' intuition so that it can be constructively used in the appropriate situations (e.g., Hogarth 2001; Miller & Ireland 2005). Consistent with earlier research, the key ingredient for educating intuition seems to be developing an environment that supports slow learning with fast feedback but a lenient approach to errors. Miller and Ireland, for instance, suggest that professionals analyze their decision-making domain with particular attention to the available cues and the weighting factors of these cues. This knowledge should prepare the professionals to make analytic decisions, but if context factors prohibit this analytic processing in a particular instance, professionals should review the decision as soon as possible after it is complete to update domain knowledge about the validity and weighting of different cues (Hogarth). Professionals should be particularly alert for new cues or new cue usage (e.g., new context for known problem) that must be attended or considered in decision-making.

These recommendations may be extended to HCI. For some business tasks, it may be similarly important to maintain a serial, analytic HCI altogether. For productivity tools such as Excel, though, professionals may find that common workflows and macros can be reviewed after decision-making errors and on a regular basis to maintain their reliability. The measurement instruments used to examine intuition in management decision-making may also be useful to examine technology (see Sinclair and Ashkanasy, 2005 for a review).

Intuition in Naturalistic Decision-Making Research

Researchers have investigated a cognitive ability that operates within many attributes identified in the above intuition research as also characteristic of the domain of naturalistic decision-making. This naturalistic decision-making is typically described as the use of experience to make accurate decisions quickly while avoiding the limitations of analytical cognition (Klein, 1993). Klein began developing this research area from his investigation of firefighters and their ability to respond accurately to complex, changing, and stressful situations. He was particularly intrigued by fire commanders' reports that they did not consider many alternatives before deciding on a course of action but instead acted on the first strategy that came to mind. The commanders could not always pinpoint the key reasons for selecting these strategies that often proved to be optimal in post hoc review. As Klein investigated these scenarios and considered similar decision-making environments for military maneuvers and emergency medical teams, he discovered that in fact commanders actually executed a systematic evaluation process that was quick and optimal due to the level of practice and knowledge they had acquired. Just as with intuitive decision-making, there were also precursors to selection of the optimal strategy based on attention to relevant cues and approaches for managing incomplete knowledge. In addition, naturalistic decision-making could accommodate novel contexts and response needs through hypothesis generation, controlled experimentation, and mental simulation. These ideas were originally proposed in a recognition-primed decision model (RPD) in 1993, but the model was enhanced in 1997 to accommodate the different levels of evaluation.

Klein's (1997) RPD model is presented in Figure 3. The simplest situation (Level 1) is shown in the left process flow. As the situation is experienced here, the decision-maker matches the situation to a known prototype for which the current situation is typical of or analogous. As this match is recognized, four by-products of the recognition are created to guide execution of the typical response to this situation: expectancies, relevant cues, plausible goals, and typical action. Similar to their use for intuition in a dynamic environment, expectancies for each action in an action sequence prime the individual to recognize responses to each action, confirming the accuracy of the situation assessment. Relevant cues are primed so that the individual will prepare desired actions and attend to most relevant cues. Plausible goals set an endpoint that allows the individual to evaluate whether the action is progressing in the correct direction. Typical actions are suggested by prior experience in similar situations. Because context and environment are important components of the situation assessment, they often constrain the alternative set sufficiently to facilitate a single match.

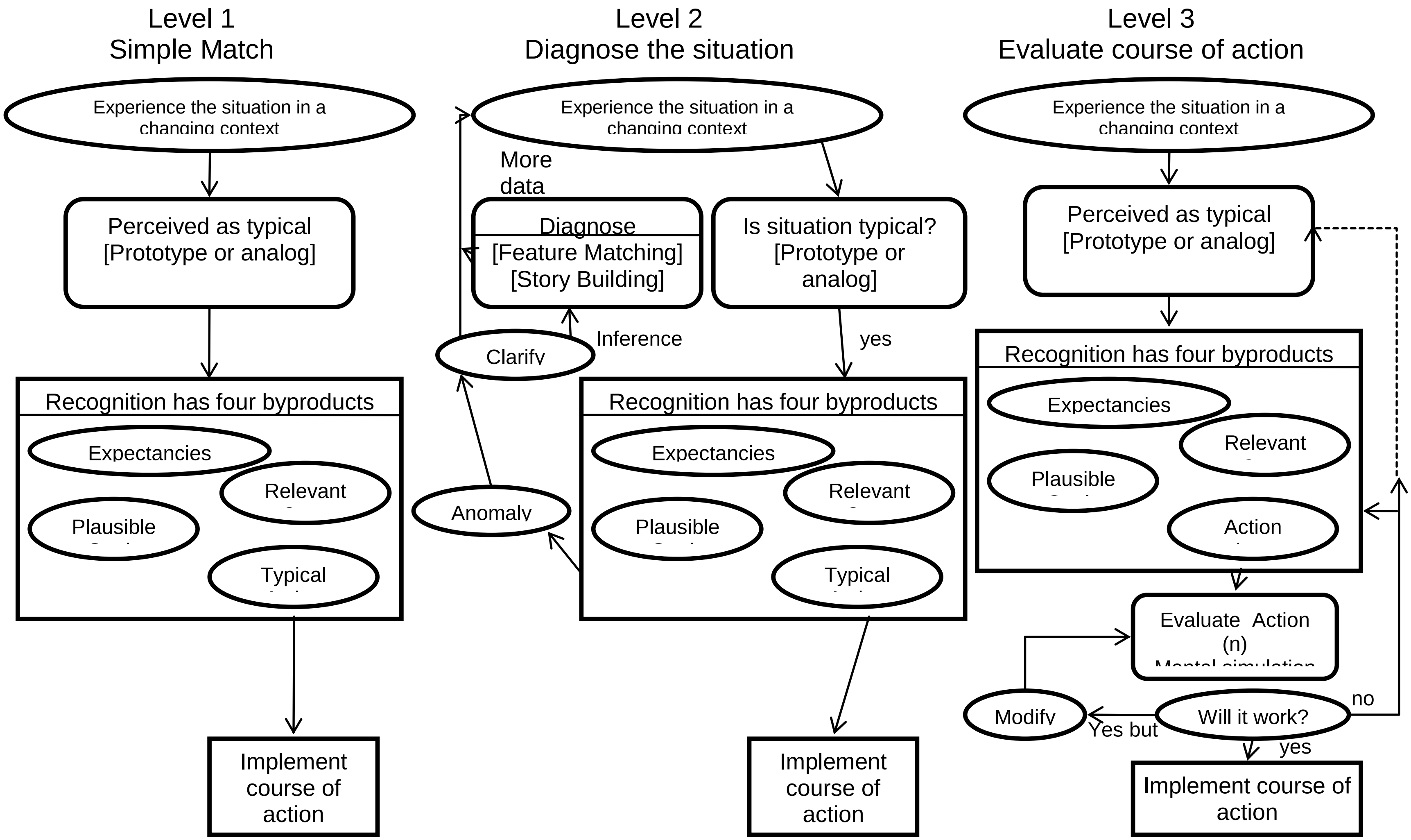


Figure 3. Modified recognition primed decision-model (from Zsambok & Klein, 1997, p. 286).

Level 2 situations (in the middle of Figure 3) are more complex because a single match is not available. Using the same type of story-building used by juries and medical decision-makers, individuals try to create a story that is coherent, unique, and fits the available features/cues in the environment (Pennington, 1993). Once a plausible story is recognized and the by-products are created, the individual will mentally review the current situation and the story to confirm a fit. Researchers suggest that decision-makers typically try to identify constraints based on causal inferences that help them to reject a possible scenario rather than looking for confirmation (Klein, 1993). If additional data is needed to clarify a situation or to identify a single match, decision-makers seem to be frugal, gathering only enough data to discriminate the options (Rasmussen, 1993). All action consequences may not be considered because of this frugality; however, doubts about the correctness of a selection may actually improve the decision-making because they will guide the search for particular reasons to de-select the course of action or a better solution altogether (Lipshitz, 1993). Once the match is sufficient, expectancies, plausible goals, relevant cues, and typical action are used as described in Level 1.

Level 3 situations (on the right in Figure 3) are more complex because multiple actions will be required in a selected course of action and the dynamic nature of the environment indicates that several of the actions in the sequence are not immediately available. For instance, fire commanders may recognize that they need to send separate teams to attack a fire from different locations, but several of the teams may not be able to reach their location until a pathway is cleared. Thus, the critical component of Level 3 RPDs is the mental simulation conducted by the decision-maker to determine if the selection will work. In the simulation the decision-maker will have to anticipate potential constraints on action execution and either modify the selection to adapt to these constraints or select a different scenario altogether.

Intuition in Cognitive Engineering Research

Cognitive engineering research facilitates an understanding of intuitive interaction through investigation into the "creation of environments to promote skillful and effective human activity" (Kirlik, 1995, p. 69). This section will discuss two specific areas of research. First, control theory allows an open-loop approach to efficiently processing stimuli and events, helping to explain complex human-technology behaviors such as driving (Hollnagel, 2002). The review of this theory will focus on the use of feedforward as a critical expectancy that controls intuitive behavior. Second, Kirlik's (1995; 2006) research suggests how fluent situated action (visually guided action located in a particular context and environment) can be supported by effective systems design. Reviews of this research will be limited to perceptions of immediacy, types of cues, and the contrasting/complementary roles of analysis and intuition.

Control theory's importance for intuitive behavior follows from the naturalistic decision-making research suggesting that optimal decision-making can be achieved with limited planning time and effort (Brehmer & Hogarth, 1990). Feedforward control is the specific mode of control that conserves planning time by eliminating the dependencies on delay and response evaluation times that typically challenge dynamic decision-making. Instead, feedforward is based on a predicted future state of the environment, moving in the direction of the goal until a constraint or blockage is met that requires additional evaluation of available actions in the current context to select the next action. These predictive models are more complex than feedback models, and participants are slower to use them because of the effort required in making the prediction (Brehmer & Hogarth). They do, however, allow the individual to maintain a flow of continuous behavior even if feedback is delayed or absent. They can also be simplified by incorporating an estimated completion time for future actions to predict a need for future resources or allow flexibility to adapt to a changing environment with interdependencies between current and future actions (Hammond, 1988).

Feedforward control is rational because it allows control based on reason, experience, and the situation as a whole rather than allowing human performance to be purely reactive or error-controlled (Hollnagel, 2002). Correct anticipation is based on prior experience or knowledge, generally due to causal relationships between the action and anticipated response (Hollnagel, 2005). In addition, the quality of available information and context/environment regularities are also important components of effective feedfoward control as may be observed with regular driving behavior. Opportunistic feedforward control may also be used in environments with time constraints or low error concerns if there are perceptually dominant features in the environment with well-learned response sets. Thus, feedforward control is suggested by several of the attributes previously associated with intuitive behavior.

Cognitive engineering also provides insights on fluent situated action, which may be analogous to intuitive human behavior. In general, humans can experience a feeling of directly and immediately knowing an object when they encounter the object through proximal senses. Even familiar, distally perceived objects through vision are experienced as direct in spite of probabilistic access to these objects (Brunswik, 1943, cited in Hammond, 1996a). Kirlik's (1995; 1998) research suggests that good system design can facilitate the perception of immediacy and directness by supporting deterministic rather than a probabilistic access to the distal environment. For example, a short order cook is shown to manipulate the environment (arranging meat on a grill) to make proximally available the distal information about meat doneness on the hidden side. He also discusses an experiment (Kirlik, Jagacinski, & Miller 1993, cited in Kirlik, 1998) in which participants monitored proximal variables that covaried with a distal variable. Systems that permit users to act on variables in a manner that reveals additional information will then increase perceptions of immediacy of the additional information, which could lead to more intuitive interactions.

System design can also facilitate intuitive interactions by presenting variables in ways that are consistent with general intuitive behavior. For instance, the perceptual system operates on the continuous variables in the world, but computers typically operate on discrete variables. If the computer display presents the user with continuous variables (though known to the computer as discrete variables), though, individuals are more likely to interact with the computer in an intuitive fashion (Degani, Shafto, & Kirlik, 2006). Similarly, automation is typically presented on computer displays in a unique, salient fashion. In an experiment in which the automation was suggested as being reliable but not perfect, participants tended to treat a unique presentation of automation as the most relevant cue. Thus, they over-relied on the automation. When automation was presented saliently but consistently with other relevant cues, participants used the automation correctly even though instructions about automation reliability were the same as in the previous experiment (Horrey, Wickens, Strauss, Kirlik, & Stewart, 2006).

Cognitive engineering researchers have suggested complementary roles for analytical and intuitive modes of processing that are somewhat different from the roles outlined in general decision-making literature. They agree that the intuitive system is efficient and generally effective, so this system should be leveraged as much as possible to free the analytic system for four specific roles (Degani, Shafto, & Kirlik, 2006, p, 187:

1) Noticing potential anomalies;

2) Monitoring the effectiveness of intuitively driven behavior;

3) Directing attention to novel events; and

4) Resolving conflicts when multiple and competing intuitive judgments or decisions must be arbitrated.

Intuition in Neuroscience Research

Limited research on intuition has been conducted in the field of neuroscience, so this section can only present results from two studies investigating specific attributes already discussed in this chapter. Lieberman (2000) reviewed the neuroscience literature to examine similarities and differences between implicit learning and social intuition, cognitive functions that were only conceptually supported by a common characteristic of the ability to demonstrate knowledge but not verbalize it. The review identified common structural components for both cognitive activities in the basal ganglia (specifically in the caudate and putamen).

Volz (2006) used fMRI to examine differential evaluation for intuitive judgments. Participants made coherence judgments on meaningful and non-meaningful gestalts. As expected, activation was found in the medial orbito-frontal cortex, lateral portion of the amygdala, anterior insula, and ventral occipito-temporal regions that have been found to be used in emotionally-driven judgments. Though no new attributes were uncovered by neuroscience research on intuition, these results suggest that intuitive judgments can be investigated using neuroscience techniques.

Summary of Literature Review on Intuition

This review of intuitive research in psychology, management science, and cognitive engineering has identified three important factors that may contribute to a definition and measurement of intuitive behavior. First, research has established a reliable model and test for intuition in Westcott's 1961 and 1968 studies, ACT. An additional model was identified in a study (Bowers, Regehr, Balthazard, & Parker, 1990) not already presented because it did not fit into any of the specific research domains and did not suggest any new attributes, but it will be discussed in this section because it revises the ACT into a test that has been used in other intuition experiments (e.g., Volz, 2006).

In the Bowers, Reghr, Balthazard, and Parker (1990) study, three experiments were conducted to judge the coherence/incoherence of three words (Dyads of Triads test), to judge the coherence/incoherence of gestalt drawings (Waterloo Gestalt task), and to examine up to 15 words to determine when participants knew the correct associate (ACT). Measurements included correctness of solution, guiding index, guiding index for levels of confidence (0,1,2), confidence in answer, clue number on which correct hypothesis is achieved, and number of clues from hypothesis to solution. Results of the first two experiments showed similar responses: participants more often discriminated coherent triads and coherent gestalts they could not solve, though they showed increases in the guiding index and increasing confidence in their answers. Results of the ACT demonstrated that the implicit knowledge of coherence guided participants in generating a solution until they could identify an explicit hunch. Similar to other studies, no evidence of a sudden discontinuity of answering was found until participants were explicitly aware of the solution. Bowers, Regehr, Balthazard, and Parker proposed two stages of awareness in their model of intuition, which is also similar to the Westcott (1961) model. First, the initial cues and accumulating pattern of cues activate relevant mnemonic and semantic networks. Second, the pattern of activations is organized and synthesized until the threshold of awareness is reached. The guiding index of increasing confidence may therefore be an effective measurement to track the development of intuitive behavior in HCI.

Second, the review has highlighted five research trends that parallel similar challenges for investigating intuitive HCI. The first trend is to specify and intentionally elicit the correct mode of cognition in a decision-making or action environment. Tools for identifying intuitive vs. analytic behavior include: the Hammond, Hamm, Grassia, and Pearson (1987) model of task-inducing characteristics shown in Table 1; the initial (Hammond, Hamm, Grassia, & Pearson) and revised (Hammond 1996a) cognitive continuum index shown in Table 2; the process characteristics and content for two cognitive systems (Kahneman & Frederick, 2002) shown in Table 3, and the specific role of analytic vs. intuitive modes suggested at the end of the cognitive engineering section (Degani, Shafto, & Kirlik, 2006). Related to this trend is the education of intuition so that it is correctly applied when it is used.

The second research trend is to better understand the role of emotion in intuitive behavior. The third trend is to evaluate the role of familiarity in selecting knowledge and experience used in intuitive behavior. The fourth trend is to investigate individual differences in intuitive abilities and in preferences for intuitive decision-making. Individual differences in demographic variables such as the effect of age on preference and intuitive abilities have not been explored. The fifth trend is to determine how experience can be used through feedforward control and manipulation of distal variables to facilitate fluent situated action.

The third contribution is to identify the most important attributes of intuition. Although 16 attributes were identified in three early studies, additional intuition research uncovered a total of 112 attributes that have been investigated. Attributes were coded based on domain of research and then color-coded to designate initial research source, but patterns of findings still did not emerge. Instead, we observed that similar attributes were described with synonyms or minor elaborations that made it difficult to determine where the research was aligned and where results differed. Even the last "attribute" of contrasting intuitive vs. analytic thought was more of a framework to help researchers clarify what intuition was not than what it was. Comparing attributes against the *intuition's* dictionary definition and etymology confirmed similarities because of the use of knowledge/experience and perception-like qualities such as immediacy and low effort, but there were clearly additional relevant factors like recentering and expectancies that had been considered.

Therefore, we reorganized the attributes into an initial framework as shown in Appendix B. The initial descriptors for 17 attributes are listed in the first column, with synonyms and elaborations from other research listed in the same row next to the key descriptor. Each synonym or elaboration is color coded to indicate the first reference for this term. For discussion in subsequent chapters, we rely on the simplified version of this table shown in Appendix C. The simplified listing contains only the key descriptor (from the first column of Appendix B).

CHAPTER 3: NOVICE COMPUTER INTERACTION

Introduction

Early computers were expensive, and thus computer operators were carefully selected and trained to use them correctly. As computing costs and size dropped, manufacturers began to develop desktop and home-based computers that users might be able to learn on their own or with little training. By observing how these users interacted with computers, investigators developed an understanding of the previous knowledge applied to these interactions. They could also observe how this knowledge was used and helped users gain additional procedural knowledge to help them achieve functional goals. If the knowledge use appeared to be immediate and gained in the same way as perceptive insights, these interactions might be characterized as intuitive according to the first dictionary definition of intuition (see Chapter 2).

For the purpose of developing a bottom-up perspective on intuitive HCI, this chapter presents a chronologically ordered review of research on novice computer interaction through computer interface development. In addition the discussion identifies different attributes of the environment, user expectancies, etc. that affect novice use. This research includes several experimental studies in which factors that may affect intuitive interaction were manipulated. For the most part, however, this research has documented case studies of novice behavior and theories proposed to explain this behavior. Thus, this research did not investigate intuitive behavior per se, but the research often identified characteristics of novice behavior and learning that map to the attributes of intuition described in the previous chapter.

Introducing Typists to Word Processing

A team of researchers at IBM’s Watson Research Center (e.g., Carroll & Mack, 1984; Carroll & Rosson, 1987; Lewis & Mack, 1982) investigated how experienced typists used the computerized word processing systems being developed in the early 1980’s. In particular, a think-aloud case study of ten experienced typists learning to use word processing systems with little guidance over 4.5 days provides a rich source of behavioral data for identifying interaction attributes that made learning easy and difficult (Carroll & Mack, 1984). Generally, the researchers noted that users may be motivated to learn a new type of system, but they may not be able to easily transfer a metaphor on their own or teach themselves to effectively use a system. With sufficient motivation users could gradually learn how to execute key functions by experimenting with the functions rather than by studying the manual. They used function labels to set expectations for function operation and learned from feedback what the function actually meant and the label signified. Users were active and creative in incorporating new knowledge (of the word processing system) into their old knowledge (prior typewriter knowledge and word processing functions already learned). Because word processing systems, unlike typewriters, were more tolerant of errors and errors were easier to repair, researchers speculated that users may have been more willing to explore these systems.

Exploration was non-systematic, however, and ad-hoc reasoning and observation may have created problems as much as they solved them (Carroll & Mack, 1984). When users made mistakes, they were often disoriented and further complicated the mistake through misinterpretations of coincidental events. The typewriter metaphor also created several problems because of non-transferrable functions. Users did not understand why they could not type in document margins or the difference between save and close functions that both produced the same visible result (i.e., the document disappeared from the screen). Completely new functions such as file management were also very difficult for participants to discover.

High typing self-confidence but low computer self-efficacy produced mixed results (Carroll & Mack, 1984). On the one hand, apparent progress toward completing a task allowed users to continue to operate from a previous error until they reached a fixed constraint (i.e., the closed rather than saved document could not be retrieved for editing). On the other hand, users often blamed themselves for not being able to complete difficult tasks that were not clearly labeled or guided.

To conclude, the researchers proposed several recommendations for improved system interface design. First, they recommended that users are given responsibility to explore along with control and immediate feedback to govern their exploration and evaluation. Second, they recommended that systems have an automated training support that provides a progressive disclosure of functions to guide the exploration and increase users' confidence in their growing knowledge and understanding of the system. Third, they suggested that users are provided with a framework for self-orientation and recovery to help them recover from errors and feel progress toward their goal. Finally, they recommended that users are given a perception of safety with knowledge about constraints (i.e., what will not happen?). Carroll and Rosson (1987) concluded their review of several studies with the observation that designers "cannot match users' naïve intuitions about how things work. [These] may even be irrational. […] You must conduct a thorough test with your target users, get feedback, and evaluate the feedback to learn how they may behave." (p. 97).

Thus, even for these early "intuitive" systems, user errors led researchers to conclude that interactions should be guided. Interaction factors such as "feelings of correctness", recentering, and willingness to guess may have led to intuitive use based on prior experience, but the experience was used in somewhat unpredictable ways. The next set of studies investigated more specifically what experience transferred and whether it could always be beneficial.

Learning and Transfer of Text Editing Skills

This empirical study examined how individuals learned line editor and screen editor word processing programs and measured the transfer of skills between the different programs (Singley & Anderson, 1987). Two experiments were conducted within this study. In the first experiment proficient typists with no computer experience learned word processing from a set of three text editors, two line-based editors and one screen editor, over six days. Participants were taught a minimum set of commands on their target system before editing book chapters. After two days of editing, the participants on the line editors switched to the alternate editor, were retrained on the new system and continued editing. After four days of editing, all participants began to use the screen editor (EMACS) on the fifth day. A control group of participants who had just been typing the chapters on a typewriter were also moved to the EMACS editor.

Results showed that participants improved their performance gradually on all text editors (Singley & Anderson, 1987). Analysis of the transfer results showed that participants almost completely transferred function execution between the two line editors. These participants transferred most of the functions between the line editors and EMACS, with differences based largely on access to elements of previous commands in the new editor. In fact it appears that participants transferring to a new system relied on the familiar method if it was still available, and only updated their knowledge if the function was new or if the command was clearly easier than the previous method. Performance improvements were largely based on reductions in the planning components of the skill.

The second experiment used a similar method but added a “perverse” version of EMACS that created new commands for key EMACS functions to try to maximize interference between the text editors (Singley & Anderson, 1987). For this experiment, proficient typists with no computer experience edited documents on combinations of EMACS, perverse EMACS, and a line editor over six days. As with the first experiment, all participants improved on the primary editor and learned the EMACS editor. The introduction of the perverse EMACS, however, interfered with performance on the EMACS editor more for the group that had only learned EMACS than for the group that had also learned the line editor. The experimenters speculated that the second group (learning the line editor first) had established a more generalizable set of editing skills based on exposure to two quite different text editors. The first group (learning only EMACS) had learned different perceptual motor commands for the same function, neither of which was more accessible than the other after exposure to both. Yet, this first group still did not show negative transfer between the two versions of EMACS.

Detailed analysis of the keystrokes selected identified several instances in which participants actually used nonoptimal commands to execute the functions. The few instances of negative transfer observed were better characterized as positive transfer of nonoptimal methods rather than instances of true procedural interference. Participants seemed to have used similarities between commands or cues to select the most accessible execution method.

As with the first experiment, performance improvements were a result of reduced planning time and elimination of supporting steps in a procedure. All declarative knowledge about the text editing process flow transferred successfully across text editors. Transfer findings were generalized to suggest that transfer occurred when the planning for particular functions was similar, but no high cost or absolute constraints prevented the user from using the previously learned command. Transfer might not occur, however, if an alternative command is more salient or has lower cost (see also Gray & Fu, 2004).

These studies provide specific recommendations about what knowledge will be transferred, but note also that not all transferred knowledge is beneficial. Given environmental factors that promote trial and error, people may not learn the correct way to use a system, particularly if implicit learning is involved. The next study takes a broader view of the problem by examining factors of a new system that might allow individuals to more easily use them.

Theory of Easily Learned Interfaces

As discussed in prior sections in this chapter, novice users have been found to take an active role in discovering the functions of a new system. Similar to the goals of educators described in the previous chapter, however, user-friendly systems need to structure information in an organized way to guide exploration according to their goals and without feeling like they are being forced to use someone else’s process. System designers seeking particular guidelines or features that must be included for usable systems were frustrated to find that intensive empirical testing was the only way to incorporate science in what was otherwise more like an artistic endeavor (Polson & Lewis, 1990). The theory of easily learned interfaces was developed to synthesize findings from case studies and research on specific aspects of design to provide structure to the art with a theoretical foundation for exploration (Polson & Lewis). It was based on experimental findings from problem-solving research.

According to Polson and Lewis (1990), the first key to usable design was to reduce the amount of new knowledge that had to be learned for effective use of the system. With new systems users have found that it is difficult to create sub-goals to support achievement of an end goal. They are also unlikely to be able to evaluate available actions to select the one that is most likely to help them achieve the goal. A second approach for new systems is to present a structure on the interface that allows users to efficiently search for the first step in using the system to achieve a goal. Given these potential barriers, Polson and Lewis proposed two mechanisms that allowed individuals to easily use the correct previous knowledge if it was available or to evaluate potential actions if previous knowledge did not appear to be relevant.

The first mechanism was label-following through which users selected obvious surface cues to identify labels that best matched the goal based on perceptual similarity and probability of progressing toward the goal. Good matches increase the user’s confidence that selecting the label helps progress toward the goal. If only one label or action was available, users will choose that action if no penalty is involved because they infer that the action must be on the way to the goal. If familiar labels do not match the goal, users will search among novel uses of familiar words or technical terms as these suggest actions that may have an unknown consequence. If nothing seems likely, users will pick at random. Two recommended keys to design used with label-following are effective labels (identified via focus groups within design) and feedback that clearly informs the user of their current path.

The second mechanism was hill-climbing that involves the search for an optimal solution in a problem-space. Based on the response to the previous action selected, users must analyze the effect of choices, particularly to identify causal relations between actions and responses that are most helpful in developing a system representation sufficient to plan future actions. Because this mechanism involves a learning component, users may select actions that help them to refine their system representation by finding actual and artificial constraints. This mechanism allows users to organize results based on perception of coherence or sense of relations even if the organizing principle for the system is still unclear. Thus, additional keys to design for hill climbing are a lenient attitude toward errors and low cost for selecting actions based on guessing. In fact, Polson and Lewis (1990) proposed that easily learned interfaces are based on design for successful guessing. The complete list of design principles for successful guessing (Polson and Lewis, p. 214) is:

1) Make the repertoire of available actions salient;
2) Use identity cues between actions and user goals as much as possible;
3) Use identity cues between system responses and user goals as much as possible;
4) Provide an obvious way to undo actions;
5) Make available actions easy to discriminate;
6) Offer few alternatives;
7) Tolerate at most one hard-to-understand action in a repertoire;
8) Require as few choices as possible.

Note, however, that external factors such as the environment or a broader focus were not considered, nor were more subjective factors about “certainty of correctness” or emotion. The next study addressed the individual difference of age to examine the effect on system usage as well as elaborating on how participants use guesses to learn how to use a new system.

Design of Home Appliances for Young and Old Consumers

This study consolidated findings from several case studies that report older adults’ challenges with technology and examined use differences in programming a new TV/VCR between younger and older adults (Freudenthal, 1999). The study confirmed that age differences representative of novice computer use exist. Similar to findings from Carroll and Mack’s (1984) earlier study with younger and middle-aged adults, five of ten older adults did not know how to work with menus. They did not find them easy to learn in general, with specific problems understanding labels and managing the cursor. They did not understand the principle of confirming actions and could not easily discriminate between response feedback and available action listings to understand the typical action/response cycle.

Although Freudenthal (1999) proposed that differences in working memory may partially account for the older adults' difficulty in using technology, she speculated that the primary reason was differences in technology generation. Analysis reported earlier in this study proposed the importance of age of technology introduction to knowledge acquisition about new types of technology (i.e., electromechanical devices where a single button controls a single function vs. menu-based systems where buttons may have multiple functions). Based on timelines for technology introductions, she suggested that current younger adults were part of a menu generation but current older adults were part of the electromechanical generation. There were individual differences between participants in each age group based on occupation, for instance, but the core principle that general experience increases with age but may be outdated for new technologies is interesting and invites further investigation.

The study also reported many observations about interaction behavior that was found in both age groups. At the general level, "users are not willing to learn [the computer or computer procedures]; they are merely willing to use [them]" (Freudenthal, 1999, p. 138). Thus, they are very selective about choosing unknown actions and memorizing operational rules and action/response cycles. If the rule was already familiar, however, it was easily recalled and confidently executed. Details were typically forgotten, perhaps because users expected that they would recognize the details if needed. Users also assumed that the device was organized logically and consistently, so action/response cycles reflect the "laws" of the product that could be inferred. Inconsistencies between similar functions and actions were particularly problematic because they decreased users' confidence that they knew the “laws”. Users were frequently frustrated by these inconsistencies, and this frustration seemed to then decrease their ability to identify an alternative approach. A level of inconsistency was expected in new versions of the system or new devices, however, which may have motivated users to persevere and attend to new functions or cues to guide recognition of the appropriate action to reach the goal.

Thus, users are rational in their use of new and existing knowledge to fill in missing information that may help them use a new system as shown in Appendix D. Specific cognitive abilities like working memory may contribute to effective use. Differential knowledge bases may affect system usage based not only on the knowledge itself, but also how this knowledge and experience using the knowledge affects system confidence. The systems examined so far, however, have generally been self-contained. The next study investigates system usage on the Internet, where user groups are even more diverse and many aspects of system navigation are outside of the control of a particular web designer.

Information Foraging

Information foraging research is based on biological research investigating how animals forage food in the wild (Pirolli, 2006; Pirolli & Card, 1999). Biological research has developed and validated mathematical models describing the cues and search strategies used by animals to identify the most productive patches of food and to determine how long to forage in that patch. Thus, naturalistic foraging examines strategies to minimize investment in between-patches time because there is no yield for the search and movement time in this period. Strategies to forage within-patches are designed to maximize food yield by remaining in the patch until the marginal yield of continued foraging in that patch is lower than the cost of changing patches.

Internet searchers face similar problems to foraging animals because they must make decisions based on information of indeterminate quality and relevance (Pirolli & Card, 1999). Researchers have proposed that searchers use an information scent (similar to the food scent for animals) to maximize the information gain per unit cost. Specifically, the information scent is the "proximal means by which a forager judges the value or relevance of distal information sources" (Pirolli & Card, p. 662). Note that the searcher must also consider access cost to the distal information based on search time between pages (analogous to food patches) with additional cost if an unproductive scent is followed. By examining specific cases of human foraging for library-based research and web-based research, Pirolli and Card have validated that the biological foraging model provides a reasonable framework for information foraging overall.

Similar to concepts of perception and decision-making from proximal cues that are only probabilistically related to the distal cues, information foraging uses proximal cues to determine whether the distal goals are available through a particular access path that is only indirectly associated with the proximal cue. The information foraging model uses access to a declarative knowledge network that is searchable through spreading activation to evaluate the potential value of different paths between proximal and distal cues (Pirolli & Card, 1999). The model also includes access to semantic networks to evaluate words with similar meanings and to visual networks that can evaluate perceptual similarity of words (and their derivatives) that may be most accessible for low-cost skimming.

As they reviewed case studies of non-Internet library-based searches, Pirolli and Card (1999) identified not only how searchers skimmed and selected target information, but they also described how searchers organized information to facilitate future searches through a process called enrichment. Similarly, web designers can enrich the environment to lead searchers more fluidly to content in their domain through careful analysis and structuring that often leverages intuitive attributes. Designers of non-content pages can improve information access to content by selecting and organizing proximal cues that will first be highly salient for searchers with goals related to the distal cues. Then, the resulting page must present the next link in the access page with proximal information that signals progress toward the goal and increases the searcher's confidence that the link selection was correct. Note that both in evaluating between-patch selections and within-patch selections, the relationship between proximal and distal cues may be based on the context that determines the relevance for the goal (Pirolli & Card). In addition, the relevance of each cue interacts with other possible cues, particularly in the environment of the page (e.g., authority of a page may be based on hosting site such as a university). Interactions between cues are also based on the individual searcher's experience and knowledge based. Thus, a user's evaluation of search page results is based on a combination of explicit (e.g., cue salience) and implicit (e.g., recent access) factors that may vary over time. These factors were manipulated and examined in the next study.

Strategic Use of Familiarity

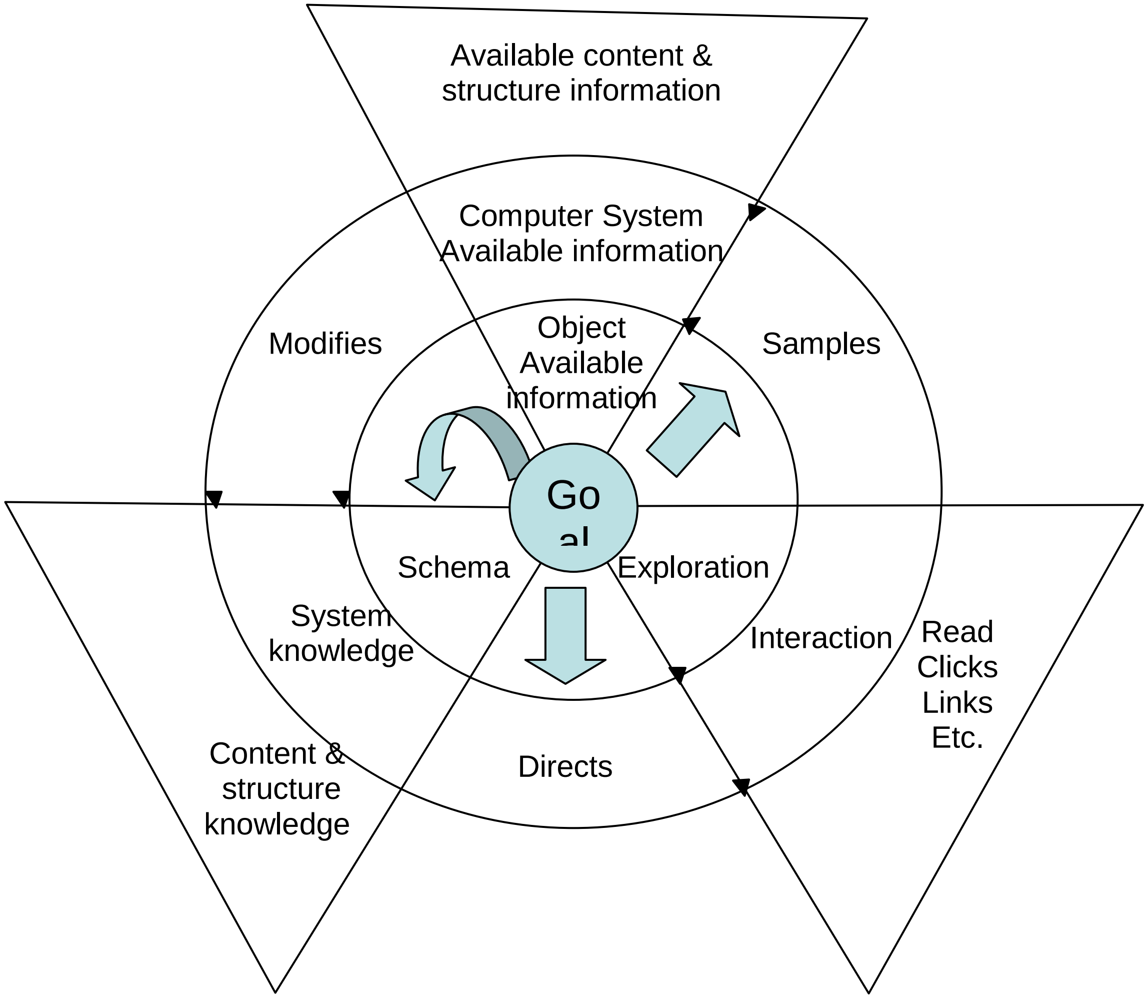
As noted earlier in this chapter, recognition seems to play an important role in system exploration so users can minimize memorization. In the current study, four experiments were conducted to investigate how familiarity and plausibility guided exploration of constrained web sites (Payne, Richardson, & Howes, 2000). Participants learned information by reading a paragraph, then explored a web site with the same information using only menu search. Web sites were manipulated in different experiments to include new and implausible information.

Results showed that participants used plausibility as their first measure for possible success of selecting a particular menu option (Payne, Richardson, & Howes, 2000). If the options were not plausible within the information provided, they would not be chosen at all. Familiarity, however, was used strategically. If the user did not reach the information goal before through a menu path accessible from the current options, they chose an unfamiliar option because they knew that the familiar options did not work. If they had reached the goal through the given menu, however, they relied on the familiarity by choosing from the familiar options. Thus, the researchers speculated that individuals realized that they forget some information, and that they are more likely to not even recognize an option when there are more choices on a menu. Feelings of familiarity could be particularly helpful in avoiding known bad choices or recognizing when plausibility or another strategy may provide more reliable guidance for directing people toward their goal. The researchers concluded that these findings could be generalized to other problem-solving domains.

This research supplements novice computer research by investigating how individuals use subjective feelings in a rational way to manage probabilistically accurate proximal information. Use of these factors may be intuitive, but it is not clear how these feelings may affect the selection and update of knowledge that seems characteristic of HCI. The last research study discusses a possible method of knowledge update.

Human-web Interaction Cycle

This research tests a proposed Human-Web Interaction (HuWI) cycle derived from Neisser's (1976, cited in Farris 2003) Perceptual Cycle of goal-based behavior, perception and cognition as shown in Figure 4. Within the HuWI cycle, achieving a goal is dependent on system knowledge (also called domain knowledge). Reviewing the knowledge leads to intention which leads to actions. These actions are followed by perception of the response which updates knowledge, which updates intention, etc.



The innermost layer is Neisser's (1976) Perceptual Cycle, the foundation for the HuWI cycle. The two outermost layers are specific to the HuWI cycle.

Figure 4. The Human-Web Interaction (HuWI) cycle (from Jones, Farris, & Johnson, 2005, p. 202)

This study investigated how knowledge is updated on a web site, but it is most interesting for its methodology that could be adapted for investigation of other intuitive variables (Jones, Farris, & Johnson, 2005). Two experiments tested the effect of schema development and inconsistent knowledge on web usage in an invented web site and domain to completely manage all of the relevant system knowledge users could bring to the task. In the first experiment undergraduate participants searched for the same set of information ten times. Web site navigation was simplified to include only back, forward, stop, and refresh commands. Results showed that all participants steadily improved their interaction efficiency with practice and were almost perfect at the end (Jones, Farris, & Johnson, 2005). Participants seemed to initially use random selections to information, but they gradually developed a coherent organization scheme for the animals to support perfect selection.

In the second experiment undergraduate participants learned an initial information packet for the same invented web site (Jones, Farris, & Johnson, 2005). Participants then completed ten cycles of information searches using one of two versions of the web site. The two web site versions represented information consistent or inconsistent with the information packet, and web navigation was limited as described in the first experiment. Results showed that the majority of participants initially used correct selections, rising to greater than 90% in cycles 3-10. Performance on the inconsistent site approached those on the consistent site by the end of the experiment, but participants on the inconsistent site continued to have search difficulties even after five cycles of eventually finding the information. The researchers speculated that participants did not in fact use a complete schema to manage their navigation as suggested in the HuWI. Instead, information was stored in multiple ways, allowing redundant access for normal usage. In correcting errors, however, corrections could only be made using the schema subset active for achieving the current goal. If the next search for the information used the previously inactive subset, errors were made again until this subset was updated. Thus, the experiments together demonstrated how users gradually built and corrected a knowledge based used for human-web interaction.

Valuable methodological components include the use of an artificial domain to control prior knowledge, measurement of navigation efficiency, and link analysis to examine interaction differences across users. Some aspects of the experimental methodology may have confounded the results, however. For instance, the modified web navigation may have elicited a different strategy than participants would normally use because participants had to adopt new controls. Additionally, other studies (e.g., Beck, Peterson, & Vomela, 2006; Ehret 2002) have shown that individuals leverage spatial information about items to guide web searches. Information on the inconsistent site may have been moved to accommodate the new categorization, confusing the cue that may have ordinarily been most salient for information search. This may have decreased the user's confidence in their prior knowledge and elicited a more random approach similar to experiment 1.

Summary of Novice Computer Interaction Research

This chapter has reviewed novice behavior in interacting with computers through case studies, proposed theories, and empirical studies. Early themes suggested that users could actively learn to use fairly complex systems that were quite different from the previous environment (e.g., proficient typists on typewriters moving to computers with word processing programs). Only two themes were consistently mentioned in all research: users should feel comfortable making mistakes along their route to the goal and they should leverage prior experience/knowledge. Three other themes were mostly consistent: recentering (discovery learning through experimentation and exploration), expectancies (using prior experience to predict result of upcoming action for faster evaluation, and type of cue (different recommendations in studies including redundancies, causal properties, labels, differential weighting of cues). None of the studies addressed perception of quick, sudden appearance, emotional involvement, or contrast with abstract reasoning; however, these factors may not be necessary or sufficient when all of the evidence is reviewed.

The consistent recommendations for "need not be correct" and recentering, along with the definitions of intuition from the design literature (see Appendix A) suggest a consensus that novice users benefit from design in which they can explore without cost. Given the type of consumer applications that novice users are typically experiencing, users are likely to see a great deal of flexibility for them to use the applications exactly as they choose. This mode of operation may not turn out to be beneficial, however, if exploration leads users repeatedly down the wrong path. In addition to wasting time, users may learn incorrect methods for particular actions (e.g., Singley & Anderson, 1987). Users may also develop poor system representations because their goal is to complete a task using the system, not to learn about technology in general or this system in particular (Freudenthal, 1999). The execution approach is facilitated by simple action execution and apparent progress that allow goal achievement without awareness of normal action-response cycles. This approach may be adequate in normal operation; however, when users are forced to recover from errors. Experimenting with a poor system representation that is only slowly updated can be extremely frustrating (Jones, Farris, & Johnson, 2005). Gaps between error encounters are particularly detrimental to updating the representation as intermittent office copier users trying to clear a paper jam can confirm.

One might ask whether recommendations based on novice computer case studies are inaccurate or merely incomplete. In returning to the first study reviewed here (Carroll & Mack, 1984), one will find a recommendation for a "training wheel" approach for new users that guides them in learning basic system operations. This study also suggests helping the user feel oriented and providing safety with constraints on actions where they probably will not need to operate. Yet, the focus on exploration and casual use of guessing as a core characteristic of "intuitive" in the design literature (Appendix A) suggests that the guidelines are incomplete and perhaps incorrectly weighted. The next chapter will review a more comprehensive set of guidelines for human-computer interaction to investigate this hypothesis and evaluate the direction of more recent design research in the context of "intuitive" as an implicit goal.

CHAPTER 4: HCI GUIDELINES AND NEW INVESTIGATIONS

Introduction

To the extent that our behavior is guided by external stimuli, examination of the stimuli recommended for inducing effective HCI can provide bottom-up evidence for attributes of intuitive behavior. This chapter reviews HCI guidelines and design strategies intended to induce effective system use. Guidelines are presented in the first portion of this chapter. These guidelines have evolved through 25 years of iterative design and testing to improve the standard systems pervasive on computer desktops and common Internet applications and to reduce the incidence of errors and difficulties discussed in the previous chapter (Blackwell, 2006). The second portion of this chapter presents two summaries of key aspects of desktop systems to evaluate gaps between the guidelines and intuitive attributes. The third portion of this chapter presents three new research efforts to extend thinking about design for effective use by incorporating ideas of how stimuli sensation and perception can be motivated by different design factors. Only the last two research efforts specifically refer to "intuitive behavior", but examination of these efforts along with existing guidelines and system summaries provides bottom-up support for the importance of the proposed intuitive attributes in HCI.

HCI Guidelines

Six references were selected from frequently-cited human factors, engineering psychology, and design textbooks as sources for human-computer interaction guidelines:

1) *Apple Human Interface Guidelines: The Apple Desktop Interface* (1987)
2) Connell et al. (1997)
3) Mayhew (1999).
4) Nielsen (1994)
5) Norman (2002)
6) Schneiderman (1998)

The guidelines from these references are presented in Appendix D. Each row represents a guideline, and checkmarks are indicated in the corresponding column for each reference that included this guideline. Some guidelines were consolidated where one guideline represented the more general case for a specific example (e.g., “Include undo and redo” provides a specific example of “User control and freedom”).

Three themes emerged from the overall review. First, the only guideline included in all sets is “consistency and standards”, which was not surprising considering the evidence presented in Chapter 3 for difficulties due to inconsistency (described particularly in Freudenthal, 1999). Second, all of the references except Nielsen (1994) suggest that informative feedback is provided. Nielsen may have covered similar ground with his suggestions for error prevention and recognition support, though, choosing to allow designers to determine how to balance a specific solution with the recommendation for an aesthetic and minimalist design. Third, wide support was generally provided for recommendations that constrained user inference with suggestions to provide: visibility of system status; user control and freedom; error prevention; recognition rather than recall; help users recognize, diagnose and recover from errors; and present functionality through familiar metaphor. The broad support for these guidelines suggests that these recommendations are well-validated at least for general usability.

Two references, however, provide unique patterns of recommendations or a unique focus. None of the guidelines in the Apple Human Interface Guidelines (1987) was unique, but different ones were shared with different references to present a unique pattern of recommendations. This pattern seems to include more visual display best practices with simplicity, stability, clarity, and consistency than other references, leveraging visual attention and graphical communications research (e.g., Mullet & Sano, 1995) that endorse creation of visual displays that increase user confidence. It is noteworthy, however, that these principles were foundational to Apple’s Lisa system that received many industry accolades but was found to generate similar user difficulties as discussed in Chapter 3 (Carroll & Mazur, 1986).

The other unique set of guidelines is presented in Connell et al.’s (1997) Principles of

Universal Design, intended to support universal access not only to high technology, but also to simple devices and buildings. Given this goal, the four unique guidelines for equitable access, perceptible information, low physical effort, and size/space for approach and use are not surprising. The fifth unique requirement for intuitive use is quite surprising, though it is listed without a definition for intuitive use. Personal correspondence cited in Blackler, Popovic, and Mahar (2003b) with the authors at the Center for Universal Design indicates that there is no definition because “it makes so much sense that they never questioned it” (p. 492). Thus, the guidelines for universal access support the “individual differences” intuitive attribute, and the “intuitive use” requirement suggests that further research on intuitive use is needed.

Thus, the guidelines may be going beyond general usability, though it is not clear if these changes elicit intuitive behavior. To evaluate the usefulness of the HCI guidelines as a basis for intuitive behavior, the guidelines have been re-organized into a mapping table (Appendix E). Similar to previous tables, intuitive attributes are presented in rows. Rather than listing single references in individual columns, however, the second column lists individual guidelines from Appendix D that map to the intuitive attribute. Thus, if an attribute is addressed by at least one guidelines set, the listing provides a definition for each attribute from the HCI perspective.

A review of this mapping suggests that designers may be making the systems easier to use by structuring systems to prevent errors rather than merely providing enough information for users to diagnose and repair them. Example approaches of this error prevention are restricting access to system areas that users will not want to be in (Beale, 2007) and complicating functions that the service provider does not want users to select such as live agent access at Amazon.com (Spool, 2005). Design practices that lead users to task closure by only presenting frequently accessed functions may also be highly effective for intermittent access systems that users do not want to learn. In one sense the resulting designs are less flexible but the benefits of reduced frustration and higher task completion for the overall system may help address the new types of errors raised at the end of

Chapter 3 (Spool).

By only targeting usability, however, technology enhancements may be limited to automating functions rather than encouraging new behaviors as visionaries believe technology should do (Mayfield, 2005). Guidelines may only address behavior change through indirect methods as suggested by Appendix E mapping gaps for precursors to knowledge, subjective certainty of correctness, and emotional involvement. For instance, the emergence of high quality graphic design principles that fit the capabilities of common computing technologies may inspire user confidence to rely on the system for complex tasks. This effect was demonstrated in reverse by the lower confidence in system recommendations presented in a difficult-to-read font (Simmons & Nelson, 2006). Clear presentation of cues and patterns may provide users with feedforward to set expectations for required actions and possible system responses. Feedforward may also provide precursors to insight such that sufficient information is provided in the environment to guide user selections even if the user is unaware of the guidance. One strategy that web designers use for this is including additional descriptors about a function in a more subtle font close to the salient function label (Spool, 2005).Thus, designers may be implicitly responding to some guideline gaps with new design approaches. To be comprehensive, though, these approaches must include fundamental HCI concepts described in the next two sections.

Direct Manipulation Interfaces

Direct manipulation interfaces (DMI) are the control/display combination for a computer system or other high technology in which “all operations are done in form that matches the way [humans] think about them” (Hutchins, Hollins, & Norman, 1986, p. 90). These interfaces are recommended to improve computer access for noncomputer users and novices because they leverage natural hand movement characteristics and maximize the compatibility between controls and displays for visually guided action (see Wickens & Holland, 2000 for a review of compatibility principles). They suggest that novices can learn the basic functionality easily due to the semantic and articulatory directness of DMI. Semantic directness means that the interface clearly sets expectations about how operation of the control will allow the user to reach their goal and to evaluate progress toward the goal. Articulatory directness means that the interface form clearly communicates the operation and adjustment of the control to allow the user to reach the goal and to respond to perceptual feedback from action of the DMI if necessary.

Six reasons are proposed for their recommendation (Hutchins, Hollins, & Norman, 1986, p. 90, derived these from Schneiderman, 1982):

1) Novices can learn basic functionality quickly, often by demonstration;
2) Experts can work rapidly for variety of tasks, even new functions and features;
3) Knowledgeable intermittent users can retain operational concepts;
4) Error messages are rarely needed;
5) Users can see immediately if their actions are furthering their goals, and if not, they can simply change the direction of their activity;
6) Users have reduced anxiety because the system is comprehensible and because actions are easily reversible.

In their review of these reasons, Hutchins, Hollins, and Norman (1986) discuss their support for all but the second of these reasons. In contrast to Schneiderman's second proposal that the DMI will allow experts to work rapidly, Hutchins, Hollins and Norman suggest that experts may in fact be slowed because repetitive actions cannot be efficiently executed as they might with command-line execution. Of course, this barrier for experts becomes an advantage for novices and intermittent users who naturally respond to the DMI (third proposal). Error messages are also not separately needed because the immediate visual response to the action communicates if the action furthers the goal, and the action only needs to be reversed to correct the error (fourth and fifth proposal). Users will experiment with the DMI because the cost of errors is low (sixth proposal). Thus, DMIs seem to facilitate novice computer access, though they may not provide the generality and flexibility that would experts may prefer for optimal access. They seem to support intuitive use by increasing perceptions of directness by leveraging principles for motor learning and visually guided action.

The Design of Everyday Things

Norman's book, *The Design of Everyday Things (2002),* originally published in 1988 under the title *The Psychology of Everyday Things*, is credited with educating many designers about basic aspects of human behavior that are affected by specific aspects of designs. This book applies many of Norman's findings from cognitive psychology research on system representations, mental models, and supervisory attentional systems to explain why people may encounter challenges in using even simple devices and systems. Thus, much of the research can be found in primary form elsewhere, but the descriptions of user errors provide evidence of the challenges that humans encounter in their interactions with simple products, high technology, and buildings. Similar to the way that psychologists study systematic errors through cognitive illusions to understand humans' decision-making processes, examination of human errors due to system design features may also help psychologists understand HCI (Kahneman 2005).

One of the most useful concepts from this book is the Seven Stages of Action, shown in Figure 5 (Norman, 2002). Specific points are identified in the process flow at which the interaction between human and high technology may be influenced by the design, beginning with the stage where the user forms their goal. On the execution side of the model, users transform their goals into particular plans that can be executed with the target device and within the current environment. One typical challenge is that users cannot perceive what actions are available with the target device or how that device can be used to help them achieve their goals. On the evaluation side of the model, users review feedback in response to their actions to determine if the action was correct and is helping them progress toward their goals. A typical challenge in this part of the flow is that the user cannot determine if their action was perceived by the device or how a previous action now influences the set of actions now available on the device. Norman's recommendation to address this problem is "Make things visible: Bridge the gulfs of execution and evaluation" (p. 188), which is similar to the proposed intuitive attributes of "immediate and concrete awareness of cues and goal" and “expectancies/ action-focused/ feedback”. This recommendation is one of seven recommended principles for designing appropriate devices that transform difficult tasks into simple ones. The full list (pp. 188-189) is:

1) Use both knowledge in the world and knowledge in the head;
2) Simplify the structure of the task;
3) Make things visible: Bridge the gulfs of execution and evaluation;
4) Get mappings right;
5) Exploit power of constraints – artificial and natural;
6) Design for error;
7) When all else fails, standardize.

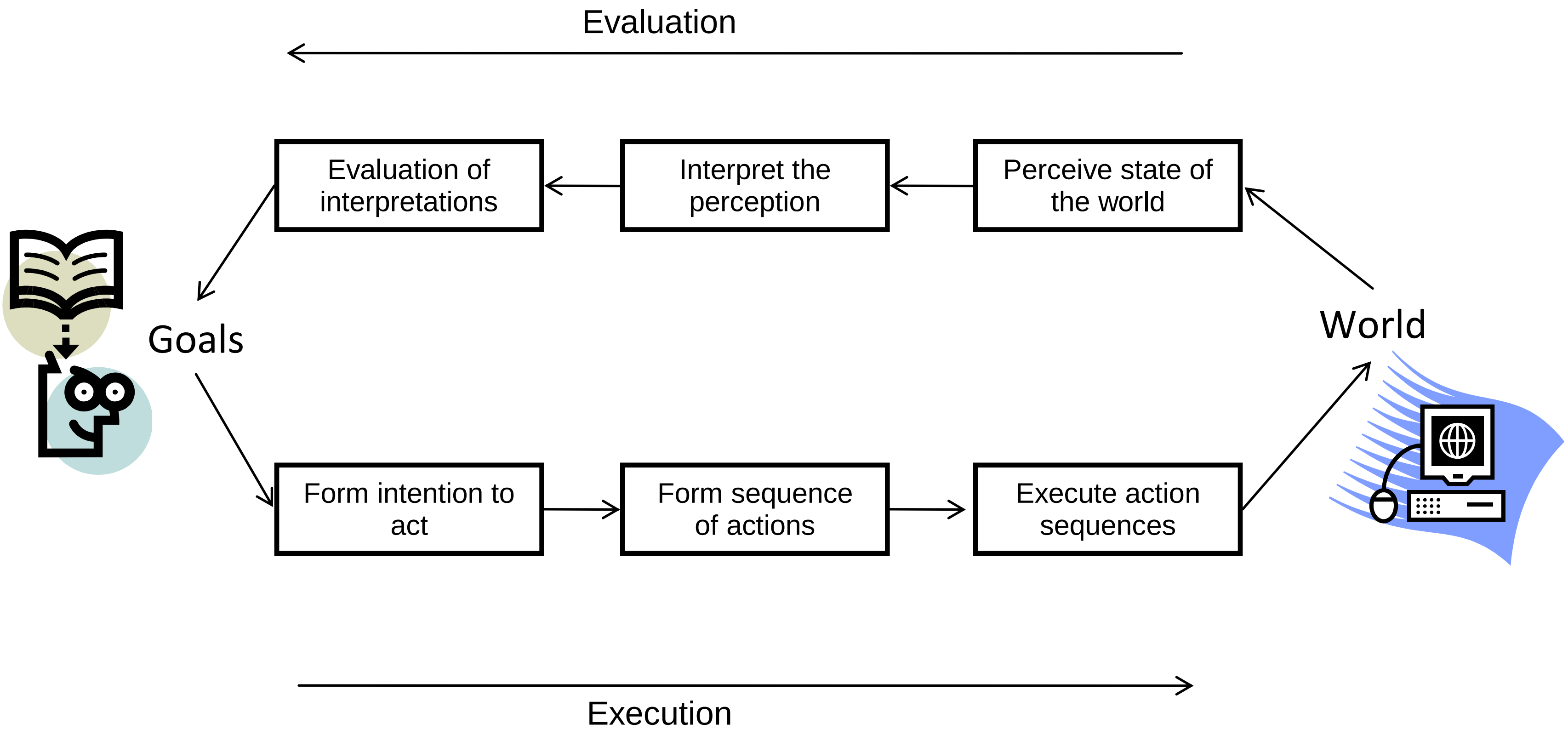


Figure 5. Norman's Seven Stages of Action (2002, p. 47)

One recommended approach for accessing knowledge in the head is to use metaphors on the display. Metaphors may suggest goals, general functions, and specific procedures to the user, helping the user to set correct expectations for available actions and usage (first principle). Some metaphors may be problematic as described in the previous chapter, but user testing with the metaphor should identify specific problems that could be alleviated through other design techniques if the metaphor is otherwise appropriate. If the task is simplified, users need little effort to identify the relevant cues to guide their action even if it is unfamiliar (second principle).

Similar to DMI concepts, selection and display of controls with natural mappings to familiar user actions allow users to leverage prior experience and natural constraints (fourth and fifth principles). These natural mappings are particularly found in affordances, a term coined by Gibson (1986) to describe the actions available to a specific individual based on properties of the environment. Norman is cited by many design researchers (e.g., Djajadiningrat, Overbeeke, & Wensveen, 2002) as alerting them to the value of using affordances to effectively communicate action possibilities to users, though he meant perceived affordances that can be learned with hands-on experience vs. real affordances which he thought were too few to be useful (Norman, 1999). A lenient system that prevents dangerous errors with constraints and provides constructive feedback for users when they make errors frees users to discover their preferred method for using a device (sixth principle). Standards represent global and domain knowledge that can be accessed to guide system usage with low cost of access because users have experience with the standards from other devices (seventh principle).

Overall, DMI and Norman’s principles particularly complement HCI guidelines by elaborating on how to elicit perceptions of directness and relevant prior knowledge. These still fail to support the need for subjective functions with “certainty of correctness” and “emotional involvement”, though. Three research teams are investigating more comprehensive approaches that fill these gaps as described in the next sections of this chapter.

Eindhoven Team of Djajadiningrat, Overbeeke, and Colleagues

As described above, HCI guidelines were formalized and disseminated beyond university settings to high technology and consumer product design teams by the end of the 20th century. In particular Norman's presentation of design-induced human errors in *The Design of Everyday Things* (Norman 1988/2002) motivated teams to design better products, though designers argued that the guidelines were insufficient for the creation of truly human-centric products (Djajadiningrat, Overbeeke, & Wensveen 2002). Instead, HCI guidelines and theories had strong functionalist orientations that neglected the breadth of humans' goals. For instance affordances may communicate action possibilities to users, but they do not adequately invite users to initiate those actions. The interdisciplinary team of researchers at the University of Eindhoven in the Netherlands (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004; Overbeeke, & Wensveen, 2003) has undertaken the task of providing guidelines that communicate and invite new actions from users as may be necessary to elicit intuitive behavior.

There are three core components to the revised guidelines. First, they recommend that designers select action forms that allow users to discover the meaning of the action based on users' natural perception-motor skills (Overbeeke & Wensveen, 2003). To do this, designers need to develop a better understanding of the capabilities of perceptual-motor skills and how particular forms of stimuli affect execution of these skills. Designers should also familiarize themselves with how controls and interfaces are more easily used by novice and intermittent users when they provide semantic and articulatory directness (Hutchins, Hollins, & Norman, 1986). Selecting and creating forms that leverage directness to communicate action possibilities allows users to take advantage of their experiential knowledge of the world as developed based on their individual physical characteristics (e.g., reach, flexibility). Interacting with these forms thus creates functional meaning for individual actions that suggests how a particular action will further the user's current goal for product or system use. Aligning execution of system functions with natural actions can thus facilitate efficient goal achievement. For example novice computer users can quickly learn to click on a button displayed on screen because their action of pressing the left mouse button is similar to that of actually pressing a physical button.

The second component of the revised guidelines is the recommendation to use feedforward and feedback to link functions and actions (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004). They define feedforward as communication that guides user actions toward intended functionality by informing users of expected results of the action. Inherent feedback communicates implicitly the relationships between previous actions and the current system state and is learned through individual experience in the world (Djajadiningrat, Overbeeke, & Wensveen, 2002). An example of inherent feedback is a changed web page after the user clicked on a link. For example, the repeated observation that clicking a mouse button on a set of blue underlined words on a web page initiates immediate presentation of a new web page allows a user to learn the function “select a web page”. The rhythm and flow of actions and responses in a particular domain becomes feedforward that helps users predict the result of actions and select functions that help them achieve their goals (Djajadiningrat, Wensveen, Frens, & Overbeeke). The researchers suggest that displaying the trace of an individual user (the exact path followed to reach a goal) can reinforce perception of the pattern and increase confidence in the system.

Lastly, the Eindhoven team recommended that designers use emotion and beauty to invite users to interact with products (Overbeeke & Wensveen, 2003). Emotional stimuli have been shown to induce immediate assessments that attract users to stimuli due to positive affect or repel them because of negative affect (Kahneman 2003; Mather et al., 2004). Emotional designs attract people to interact with products through design that suggests interactions will be beautiful, “surprising, seductive, smart, rewarding, exhilarating” (Overbeeke & Wensveen, p. 94). Thus, effective designs should allow users to seek non-functional but very human goals for attractive interactions.

One challenge of this new approach is that system designers must be educated similarly to architects and industrial designers with basic knowledge of artistic techniques and exposure to good designs. For instance, artists learn that to guide viewers in understanding a painting, they must spend time at the painting's periphery thinking about how the viewer's eye should approach the central figure for a particular purpose (Mitchell, 1996). HCI guidelines that include recommendations for high-quality graphics provide a basis for designing visual components, but interface designers must also decide how to guide users in connecting individual components on a path that will help them achieve their goal. Emotion and beauty provide perceptually-based control for this guidance that is less cognitively demanding than data-based controls such as labels and complex displays (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004). Though perhaps this research seems high-level and abstract, it provides new directions for intuitive design that goes beyond functionalist goals.

Blackler and Colleagues

While the Eindhoven team was taking a top-down approach to identifying core components of human-centric design, a team of Australian researchers was investigating design from a more bottom-up perspective to systematically measure intuitive interaction. Because this research is recent and has a similar goal as the current paper, methodological details of the experiments are presented for comparison with proposed intuitive attributes. Based on their literature review, the Australian team concluded that experience was the key factor affecting intuitive product use (Blackler, Popovic, & Mahar, 2003b). Their goal was then to develop two products to help designers create products that could be used intuitively because they leveraged user experience. One product was a tool that would facilitate selection of design components for intuitive use. The second product was a set of converging objective and subjective measurement tools for identifying intuitive interactions. The first product emerged from experiments focused on the second product, so the experiments and second product will be discussed first.

Two experiments were completed to observe usage and evaluate proposed measurements for intuitive interactions with a digital camera (Experiment 1; Blackler, Popovic, & Mahar 2003b) and universal remote (Experiment 2; Blackler, Popovic, & Mahar 2003a). Both experiments used similar methods and measurements, with minor adjustments reflecting findings from Experiment 1. Therefore, the common experimental method will be presented, but results will be discussed separately.

Participants with differing levels of experience with technologies, particularly the digital camera and universal remote, were tested in a calm and permissive environment to promote intuitive use (Blackler, Popovic & Mahar, 2003a; 2003b). Participants were instructed to think aloud as they attempted to execute two or three functions with the device, and they were encouraged to try to figure out operation by themselves without a manual. After the tasks were completed, participants completed a technology familiarity questionnaire and were debriefed through a structured interview.

Results showed that prior knowledge of features from technology in general or specifically from a digital camera allowed participants to use those features intuitively (Blackler, Popovic & Mahar, 2003b). In fact, participants with higher technology familiarity scores (indicating broad and frequent technology usage) could use more features intuitively in their first encounter and were in completing tasks. This finding suggests that broad and frequent technology usage may provide a more accessible repertoire of different features that might be used in a particular product like the digital camera. On the other hand, expert users of digital cameras with lower technology familiarity scores performed the tasks more slowly and effortfully, perhaps because these experts' functional knowledge was linked to a limited set of specific implementations. Some functions, however, were only discovered by expert users of digital cameras, suggesting not only that general technology knowledge is important for intuitive use but also that domain knowledge contributes to usage.

Familiarity and first time usage of particular features were important measurements for intuitive interaction because they allowed assessment of prior experience (Blackler, Popovic & Mahar, 2003b). Familiar features were used intuitively more often, and unfamiliar features required additional time and effort due to trial-and-error usage. Intuitive first/only uses required less time to complete. A high percentage of intuitive uses were correct vs. inappropriate or incorrect, suggesting also that intuition is generally correct but not perfect.

Results from the second experiment were similar to those from the first experiment (Blackler, Popovic & Mahar, 2003a). In particular, mean familiarity of features had a strong correlation with the percentage of intuitive uses of features and with the percentage of intuitive first uses. Anxiety may have also interfered with successful and intuitive use. Once several participants had difficulty with a task, they tried alternative strategies to continue but could not even use features they had used successfully in the past.

Based on findings from these experiments, Blackler, Popovic, and Mahar (2006) proposed three design principles (p. 10):

1) Use familiar features (including affordances, function, location, appearance of feature) from same domain;
2) Transfer familiar things from other domains to make obvious how to use less well-known functions;
3) Use redundancy and internal consistency within the product and system;

These principles were formalized into a model called the intuitive interaction continuum (see Figure 6). This continuum was created to guide designers in developing products that could be used intuitively. The continuum aspect of the model indicates that there may be a range of features available based on the type and level of knowledge available for target users. On the left side of the continuum, body reflectors is a term from industrial design literature that means products or parts for which humans can easily perceive potential fit with their body because they “resemble or mirror the body [or body part] because they come into close contact with it” (Bush (1989) in Blackler, 2006, p. 117). Headsets, shoes, and eyeglasses are examples of items that may be perceived and used easily as physical affordances (Blackler, 2006). Thus, most humans are likely to have learned their fit and functionality at an early age. On the right side of the continuum, however, only few individuals may be able to access the transferred features based on limited exposure to a particular domain.

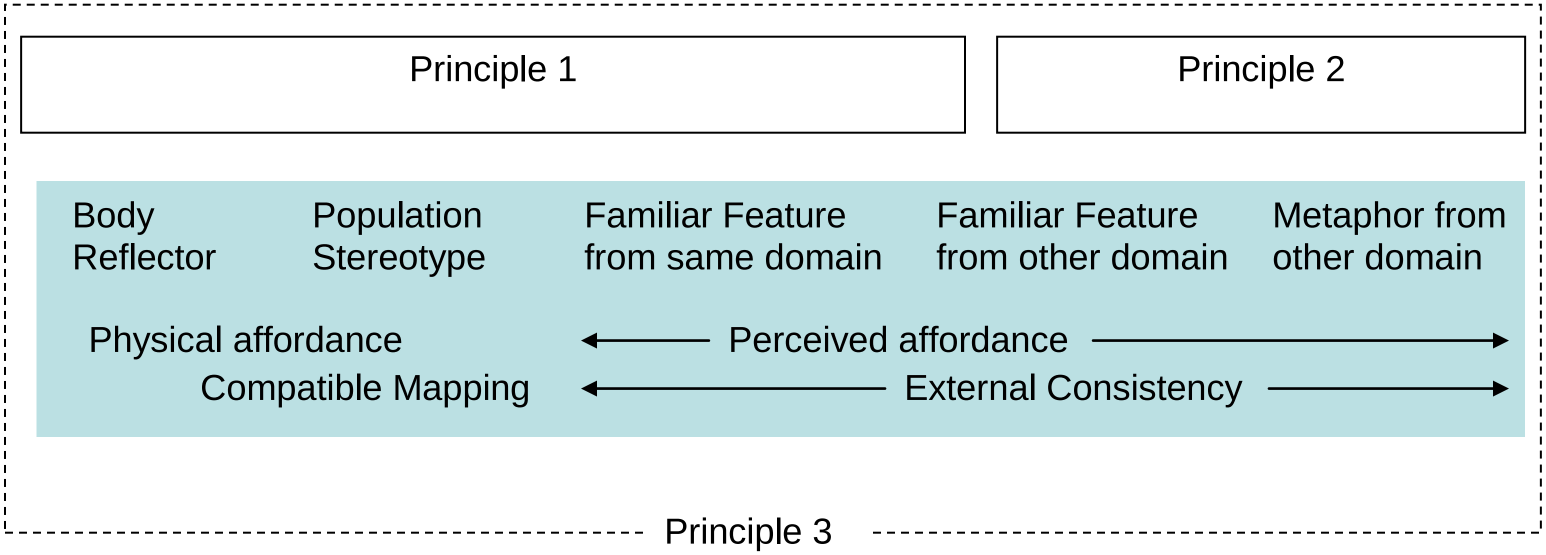


Figure 6. The intuitive interaction continuum (Blackler, 2006, p. 236)

Contributions of Blackler and colleagues' research. This research on intuitive interaction contributes to overall goal of this paper for both methodological and substantive reasons. First, the experiments demonstrate that a systematic approach to evaluating familiarity and user expectations in human-product interaction is possible. Some evidence was found that "intuitive" may be a valid construct, though the conclusions may be limited for methodological reasons described later. Secondly, the set of objective and subjective metrics increases the supply of potential metrics for further research. The methodology section of Blackler's dissertation (2006) provides additional information about why she selected the variables measured in her experiments, so there are additional possible variables that have already been evaluated.

Third, Experiment 1 clearly demonstrated a predictable difference between how users with broad technology experience but limited domain experience and users with limited technology experience but deep domain experience interact with a device (Blackler, Popovic, & Mahar, 2006). This finding informs the choice between alternative features that may be more accessible for different user groups, allowing marketing teams to merely define which user group will be more prevalent. Thus, the recommendation to educate intuition for better decision-making is supported for the design community, but with new tools to inform design.

Fourth, the continuum of knowledge and experience that could be used in design provides an interesting framework for selecting features based on user knowledge. Particularly interesting was the idea that a range of users who may find specific knowledge accessible is dependent on age of acquisition, a concept similar to Freudenthal's (1999) technology generations. It may be possible in subsequent experiments to manipulate the types of knowledge expected to be used to examine the factors leading to knowledge selection.

Limitations of Blackler and colleagues' research. There are two major problems with evaluating whether the study met the intended goals. In the general case, the research did not demonstrate anything special about intuitive interaction vs. an interaction that was merely easy to use. The dissertation background suggested that if products could be used intuitively, users would not need instruction to use them correctly (Blackler, 2006).   Yet, this definition was used to code "intuitive uses" as those actions for which no explanation of use was given, which seems to be a circular definition. Perhaps the actions were easy to see and execute but not necessarily intuitive? She also notes that her "focus is on how a user's experience informs their use" (Blackler, p. 16). The experiments indeed seem to demonstrate that differences in experience are correlated with differential usage, but the experiments do not answer the "how" question adequately. For instance, why is one set of knowledge (general) selected instead of a different set of knowledge (domain)? Is one type of knowledge better for achieving a particular type of goal? Perhaps, though, the research question is better formulated because of Blackler's research.

In the specific case, the research also shows several methodological gaps. As noted above, is the definition of "intuitive" used to code and analyze the results correct? Along the same lines, level of verbalization is the key factor used in coding intuitive uses. This attribute has been identified in prior research (e.g., Hammond, Hamm, Grassia, & Pearson, 1987), but use of this attribute for coding can be problematic because we do really know why the user did not verbalize at a particular point (e.g., perhaps they were distracted and forgot to verbalize but could still act). Using lack of verbalization as the coding criterion is also problematic because it suggests that the knowledge is unconscious, making it difficult to discover in a standard interview. As noted earlier, it can also be difficult to ascertain exactly what in the environment led to the user's implicit choice to use that knowledge. Also, although the measurements were applied in a systematic fashion, there is nonetheless a transformation of data that would be better supported with additional behavioral data. As with the earlier point, though, this experimental design can be an effective starting point for refining the methodology.

IUUI team

The need to understand design for intuitive use is highlighted by the existence of a separate and geographically distant research team investigating the same issue. An interdisciplinary team at the Technological University of Berlin, comprised of researchers from psychology, computer science, engineering, linguistics and industrial design, has been developing assessment criteria and design proposals for intuitive use (Blackler & Hurtienne, 2007). The acronym, Intuitive Use of User Interfaces (IUUI), identifies their research. At the time of this literature review, all primary research has only been published in German so this review is based on a comparison paper published by Blackler and a member of the IUUI team.

As stated in the beginning of their paper, the teams agree on many aspects of intuitive interactions starting with a high-level agreement that it is “grounded in non-conscious use of prior knowledge” (Blackler & Hurtienne, 2007, p. 37). Both teams propose models of user knowledge on continuums that inform design: Figure 6 (Blackler, Popovic, & Mahar, 2006) and Figure 7 (Blackler & Hurtienne, p. 44). In the IUUI continuum, there are four levels of knowledge listed vertically, with large numbers of individuals having general (innate) knowledge rising to small numbers of individuals with expertise/domain specific knowledge. The continuum at the top refers to ease of access for the information whereby information that is frequently encoded and retrieved is more robust in information processing terms. Blackler argued that innate experience does not provide additional information for intuitive use beyond sensorimotor knowledge, but agrees that it may facilitate intuitive interactions.

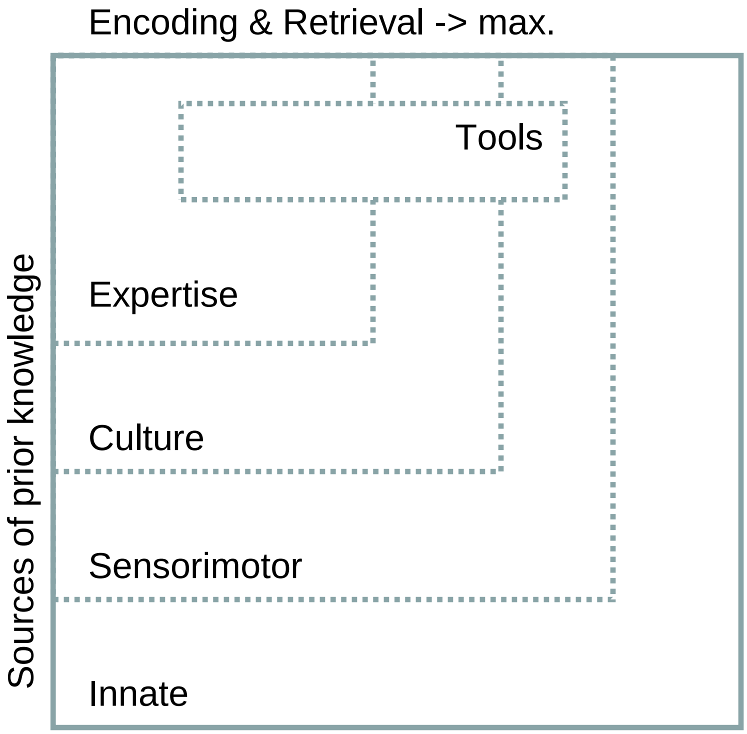


Figure 7. The IUUI continuum of knowledge in intuitive interaction (Blackler & Hurtienne, 2007, p. 44)

The IUUI also identifies seven principles of intuitive interaction; it was surprising to note that there were a minority of IUUI principles that were indeed analogous to Blackler's findings discussed here and in previous research (e.g., Blackler 2006). The shared use of knowledge, unconscious processing, and listing of different types of knowledge along a continuum may be the only common threads.

Instead, there were more similarities to research completed by the Eindhoven team (e.g., Djajadiningrat, Overbeeke, & Wensveen, 2002; Overbeeke & Wensveen, 2003). This similarity may not be unexpected because of the physical proximity of the European teams and common culture through EU membership, though comparisons have not previously been made in print. This European comparison, though, confirms similar directions between IUUI and the Eindhoven teams. Using sensorimotor knowledge as a baseline, the IUUI team has created a database of image schemas that promote intuitive use. These image schemas are “abstract representations of recurring dynamic patterns of bodily interactions that structure the way we understand the world” (Blackler & Hurtienne, p. 48). These image schemas may be similar to design patterns now advocated in web design to provide an optimal solution to a given problem (Tidwell, 2005), though perhaps only a subset of patterns can elicit intuitive interactions. These IUUI image schemas may therefore be a specific application of the Eindhoven team’s high-level recommendations to communicate action based on meaning in design.

To understand their perception of intuitive interaction goals more clearly, it is useful to examine IUUI’s target measurements. The IUUI team proposed three measurements for intuitive interaction adapted from international usability standards (Blackler & Hurtienne, 2007). They include: perceived effortlessness, perceived error rate and achievement of goals, and perceived learnability. These represent the standard usability goals of efficiency, effectiveness, and satisfaction, but the IUUI team defines efficiency as cognitive efficiency rather than temporal or motor efficiencies. With these definitions, it appears that their target interactions are still more functional and “easy to use” than related to changing behavior. Nonetheless, the products of these research areas may provide designers with tools for designing mechanisms for intuitive use as will be needed in the second phase of developing effective intuitive and non-intuitive applications (see second box in the bottom row of Figure 1).

Summary of HCI Guidelines and New Investigations

This chapter discussed how stimuli design may influence intuitive human-computer interaction. As shown in Appendix E’s mapping of the guidelines and design approaches to intuitive attributes, bottom-up evidence is nearly complete in supporting design that can influence behavior similar to that described in the top-down approach. Only “precursors to knowledge” is not represented, though it is possible that leading designers are providing these precursors without clearly describing their functional role as described within the HCI guidelines section. Design to encourage emotional involvement is still limited in the reviewed research, but it is becoming more widely addressed by prominent HCI commentators (e.g., Norman, 2005).

It is also surprising that both intuitive interaction research teams (IUUI and Blackler) are trying to identify design features that can be used intuitively rather than proposing approaches to link features together in an intuitive process. Only the Eindhoven team appears to be addressing the role of design in leading users from start to successful task completion. The combined efforts of Blackler's team and the IUUI team to measure intuitive interaction and develop tools that facilitate design and implementation this research. Before settling on tools and measurements, however, it is critical that the target of of intuitive products are perhaps the best evidence that the time is ripe for intuitive interaction has been correctly defined. The next chapter will consolidate findings from the previous three chapters to propose a model that encompasses all of these efforts.

CHAPTER 5: DEFINING INTUITIVE HCI

Introduction

In this chapter we propose an organizational framework for intuitive human-computer interaction based on the top-down and bottom-up research presented in Chapters 2, 3, and 4. The framework fits within the scope of review from Chapter 1: interaction between humans and high technology, particularly for novice or intermittent use. The proposed framework also supports the overall goals of the paper: defining intuitive interaction to support business needs analysis, requirements preparation, and usage evaluation during product development.

One major challenge in this framework is that an overall conclusion of our review is that intuitive behavior is indeed the default human processing mode, as suggested by Kahneman and Frederick (2002) and others in Chapter 2. Therefore, many psychological mechanisms are accessed in intuitive behavior including: perceptual discrimination and learning, automatic and controlled processing, visual attention, implicit learning, metacognition, declarative knowledge and procedural knowledge access, problem-solving, et al. These mechanisms, however, are individually developed in humans based on their interactions with the natural world, including other human beings. Humans may develop specific knowledge (procedural and declarative) from their interactions with computers that affects their behavior, but the mechanisms themselves are the same. As with general behavior that is mostly "intuitive, skilled, unproblematic, and successful" (Kahneman, 2003), intuitive HCI is mostly successful as well for achieving functional automation goals as described in Chapter 3.

Two problems can arise with intuitive HCI, however. First, intuitive processing may be selected used when analytic processing is the more appropriate mode, though computer designers may be in a better position to elicit the correct mode as will be described in Chapter 6. Secondly, computer designers may inadvertently develop systems that recreate natural environments in which intuition is incorrectly used as described in heuristics and biases research (e.g., Tversky & Kahneman, 1971). Thus, the primary purpose of the framework is to educate designers on how intuition works well so that it is effectively tapped. In particular a correct understanding of intuitive interaction may help designers to elicit changed behavior through technology design.

Based on the literature review, we created a novel framework that integrates relevant attributes into a coherent approach for understanding intuitive interaction. In this chapter, we will first describe briefly this new framework with reference to the original attributes identified in Appendix B. Then, we elaborate on the core components of the framework based on research already presented with supplemental psychological research as needed to justify these proposals. Lastly, we propose a definition for intuitive HCI that summarizes the framework.

Orientation to Proposed Organizational Framework

The new organizational framework is shown in Figure 8. Note that this framework is conceptual with circles used for knowledge in the world and metacognition to represent the dynamic nature of these components. The central circle for knowledge in the head also suggests that what is accessible depends on what happened just prior to the current decision, but acting upon the decision will also affect what is available for subsequent decisions and activity (as shown by the bidirectional arrows). The three “pie sections” of the framework represent cognitive activities that are all required, though the equal size of these sections is not meant to imply that each activity contributes equally to intuitive interactions, but only that all are required.

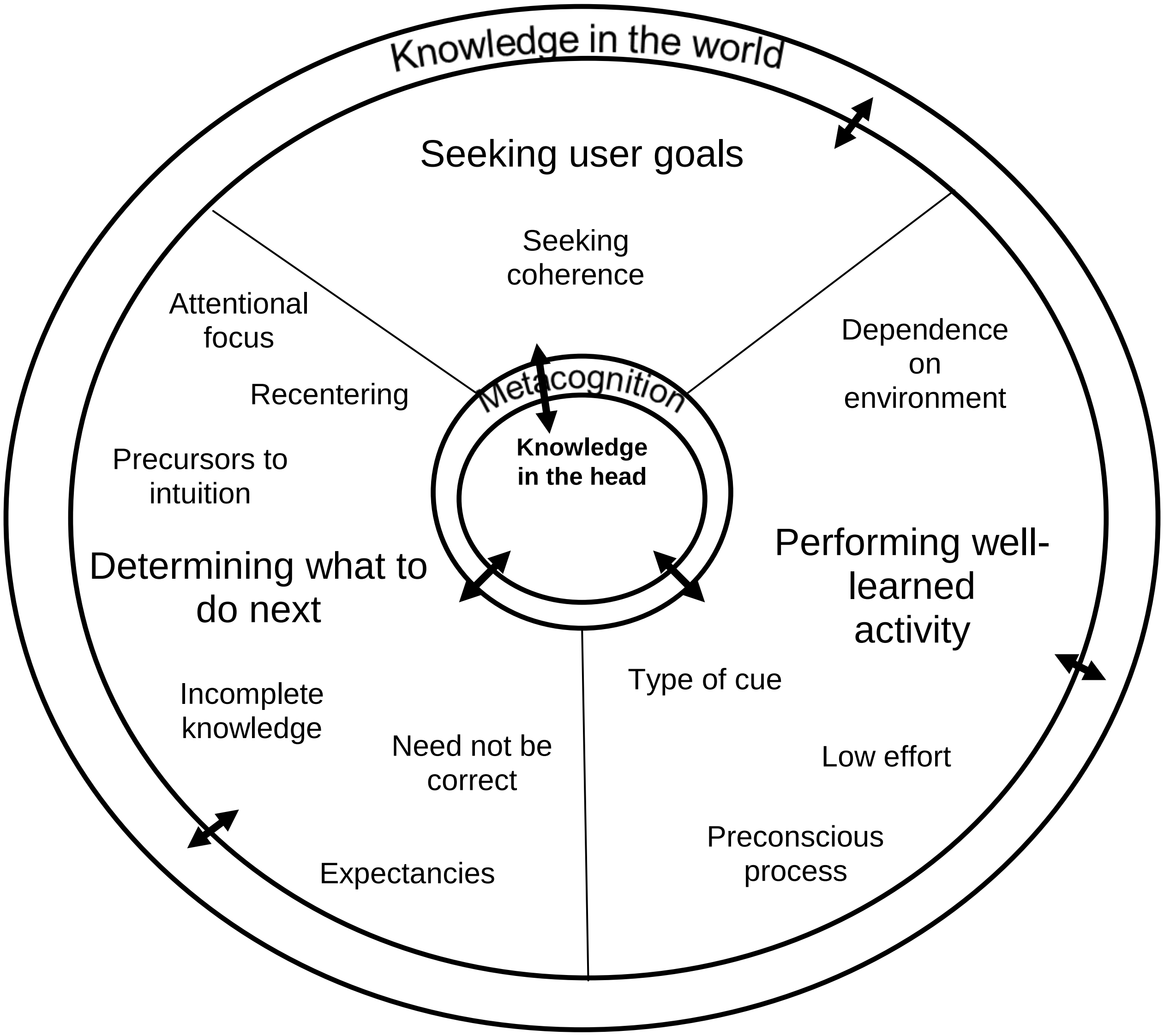


Figure 8. Organizational Framework for Intuitive HCI

Seeking user goals: User behavior is oriented toward achieving goals that may be concrete and functional like completing a specific task. The goals could also be more abstract and subjective like beauty, truth, or pleasure. A general goal of finding coherence in an environment being explored may also guide behavior and motivate perseverance as the user seeks a sense of completion from their activities.

Performing well-learned behavior: Use cognitively efficient, well-learned processes if they are immediately accessible and unconsciously judged to be appropriate for the current environment and context.

Deciding what to do next: If prior experience suggests that available cues are incomplete or unreliable and the current context is lenient for learning, use prior knowledge to suggest possible next actions. Users may mentally simulate possible outcomes of each action, using peripheral knowledge and distant associations to help them evaluate and select the next action. Online correction is provided through feedforward methods. This activity itself is well-learned and can be done with little effort or conscious attention.

Metacognition: Use the combined feelings of progress (from selected goal and progress toward goal), directness (accessibility of well-learned activity as well as perception of external information to be used), and familiarity (of proposed actions, knowledge, and simulation/fill-in techniques for this type of interaction) to select the cognitive mode and knowledge that will be used.

Knowledge in the head: Norman's (2002) book identifies this as the user's global, implicit, cultural, domain and ability knowledge they bring to the task. This was described earlier as influenced by prior experience.

Knowledge in the world: Norman's (2002) book identifies this as information in the environment including computer and other stimuli. This includes environment and task context elements.

Note that several attributes from Appendix B are not designated in the new framework. First, we interpret the literature as suggesting that emotion is not a separate intuitive attribute but is a component of each processing activity. Emotion reflects goals like beauty and pleasure that individuals may seek as outcomes for their behavior (Overbeeke & Wensveen, 2003). As Bastick (1982) described, emotion also helps connect different ideas and provides access to specific experiences to help individuals determine what to do next. Emotion also seems to elicit well-learned or even automatic responses to emotional stimuli (e.g., Kahneman 2003; Mather et al., 2004). Second, individual differences are not a separate attribute, but provide evidence of differential effects (such as with age or technology generation, from Freudenthal, 1999) that suggest ways for identifying intuitive vs. non-intuitive processing. Third, the contrast with analytic processing is also not a separate attribute but did facilitate information gathering during the literature review to help identify what intuition is not. Thus, the framework incorporates all relevant attributes from the literature, but emphasis in further discussion will describe how these elements are manifested in intuitive interactions.

Seeking User Goals

One important attribute of intuition is that it is active, used by individuals to find coherence between their behavior and the world (Hogarth 2001), though functional goals have been cited more frequently in the HCI literature. Norman's (2002) seven stages of action shown in Figure 5, for instance, are based on functional activity goals. Knowledge of these goals guides system behavior as described in theories such as the theory of easily learned interfaces (Polson & Lewis, 1990). Even goals that are not well known may encourage discovery because the loose cognitive control facilitates access to peripheral cues, increasing the opportunity for discovering new directions (Bastick, 1982). Goals can also be created ad hoc by individuals to organize a series of options that appear together on a menu bar in the context of achieving a larger goal or learning a new activity (Barsalou, 2003). It seems that the goal-seeking process itself can help link seemingly disparate items as may be needed when users explore a system for the first time, though there have been limited guidelines in the HCI literature for this purpose. Perhaps instead of just identifying intuitive features (e.g., Blacker, Popovic, & Mahar, 2003), designers should instead consider how cues are orchestrated in a system so that users can perceive a pattern that they can find through exploration.

Goals need not be only concrete and functional, however, but they can also include aesthetic goals such as beauty, pleasure, and reward. These goals may be like the "sense of something not evident or deducible; an impression" referenced as the second dictionary definition of intuition from Chapter 2. Even in early research (e.g., Bouthilet, 1948), beauty and emotion were suggested as important for intuition though this goal has not been experimentally tested or explored much further until Eindhoven team (e.g., Overbeeke & Wensveen, 2003) reconnected the ideas. Interestingly, though, Marr's (2003) examination of creative behavior noted that beauty itself provided reinforcement for Einstein's ground-breaking theory of relativity. Aesthetic goals may operate differently than concrete goals, however, where user perseverance can be reinforced more clearly by visible progress toward the goal. Instead, pursuit of aesthetic goals may be engineered by "basic behavior processes of response differentiation and stimulus control resulting in complex stochastic and dynamic webs of associative links" (Marr, p. 25). Thus, aesthetic goals designed into new technologies may be the most effective motivators for eliciting changed behaviors.

One challenge for designing to meet the requirement for goal pursuit is measuring this behavior. As suggested above, measurement is fairly straightforward for functional goals with measures such as navigational efficiency (Jones, Farris, & Johnson, 2003), but how could it be measured in more abstract and subjective goal-seeking? A measurement factor like the guiding index (Bowers, Regehr, Balthazard, & Parker, 1990) provides one approach. With this approach users could be asked during usability testing to rate their feeling of progress toward their goal. Measurements of latency between mouse clicks might also provide objective data to suggest that users are finding coherence in the information they see and gaining momentum in their progress toward the goal. Seeking functional and subjective goals could thus be measured as a "feeling of progress", a concept that will be further discussed under the metacognition subsection.

Performing Well-learned Activities

In completing many HCI activities preconsciously and with low cognitive effort, users typically select from a repertoire of well-learned skills such as mouse use and web navigation. These skills may be executed with automatic processing. For instance, psychological modeling has demonstrated that these skills can be completed in parallel at least by young adults (Kurnaiwan, 2001). Conservative estimates of younger adult computer experience, extrapolated from questionnaires reported in Farris (2003), suggest that younger adults have more than 1500 hours of experience with WIMP (Windows, icons, menus, pointing) computers and more than 2500 hours of Internet experience. As noted in Hutchins, Hollins, and Norman (1986), this level of practice allows typical WIMP and Internet usage to become nearly automated for this population, contributing to a feeling of directness. Usage of these activities may therefore be part of intuitive interaction, but the activities themselves may not be intuitive.

Three cautions must be considered by designers to facilitate well-learned operation. First, comparisons with automated processing are not quite complete. The common WIMP skill of searching for icons on a screen utilizes the central executive functions of prospective and retrospective memory to guide visual search (Beck, Peterson, & Vomela 2006). These may be the same functions that affect the asymmetric perceptual span used in reading (Rayner, 1981), another activity that is nearly automated (Schneider, Dumais, & Shiffrin, 1984). Thus, visual search seems like a very simple function, but changes in search items outside of the expected patterns can be very disruptive, increasing overall search time as the user tries to recover the automated flow of operation (Beck, Peterson, & Vomela). Designers should be careful to protect the normal flow of operations to reduce the need for effort or conscious processing.

The second caution is that users may not be aware of this normal flow or what cues allow them to execute a well-learned function so easily. Gray and Boehm-Davis (2000) have experimentally investigated subtle changes in display to recommend that task analysis should be completed at the microstrategy level to determine the best ways to facilitate behavior in system design. Otherwise, users may select a non-optimal strategy or skill as they incorporate previous knowledge into specific knowledge for the new system (Singley & Anderson, 1987). If correct execution is particularly important, a better approach for guiding users to select correct strategies is to record expert usage and “play” this strategy back for new or intermittent users. For example new radiologists have been trained in film review by viewing scan paths of experienced radiologists to gain an understanding of the feature points that attract expert fixations and path flow (Yang, Dempere-Marco, Hu, & Rowe, 2002). These guided reviews seem to convey expert feature points and scan paths more effectively than verbal knowledge. These findings support other research in which users are only aware of important cues when they are not present, so objective measures of performance with and without the cues are needed (Gray, 2006).

The third caution about selecting cues for well-learned activity use is that users often use implicit knowledge from other systems in selecting usage on new systems. Many empirical studies and HCI guidelines (see Chapter 4) suggest the importance of consistent cue and function usage between systems to allow users to leverage this prior knowledge. In using a new digital camera, for instance, users with broad technology knowledge but limited knowledge of other digital cameras could still access many common functions quickly and with little explanation (Blackler, Popovic, & Mahar, 2003b). Additional research is required to determine how users select between multiple sources of prior knowledge.

One likely explanation is that knowledge previously used in the same environment and context as the current situation provides redundancy to primary cues in the target system, reducing the probability of errors such that there is only one likely option (Hogarth, 2001). For example, lower cognitive effort may be required to select between alternative options when perceptual discrimination derived from practice in specific contexts minimizes competition between alternatives and strengthens activation of the most likely option (Schneider & Fisk, 1984). fMRI studies also seem to confirm that some elements of perceptual learning are based on context (Tsodyks & Gilbert, 2004). From a practical perspective, context has proven to be critical in action planning for expert naturalistic decision-making, though the acquisition of relevant context knowledge may make it difficult for novices to complete the same action planning intuitively (Hogarth).

Determining whether well-learned skills are being performed may involve several measurement techniques. One common technique used in usability testing is to examine the effects of divided attention on processing the primary (possibly intuitive) skill (Wickens, Gordon, & Liu, 1998). With this technique, performance on the primary task is not significantly affected by the concurrent performance of another task accessing the same resources. Another technique is to measure performance effects between designs with subtle system differences (see O'Brien, Rogers, & Fisk, in press, for a description). Several studies described in this paper (e.g., Blackler, Popovic, & Mahar, 2003b) have used verbal rationalizations and identification of cues/strategies used to identify use of intuitive usage, though previous studies have found that verbalization alone may disrupt the automatic process (McMackin & Slovic, 2000).

An alternative overall approach is to assess whether the stimuli and responses are directly perceived and executed. Concrete cues, for instance, seem to contribute to a perception of direct rather than probabilistic access to these cues (Hammond, 1988; Westcott, 1968). Emotional assessment of cues is performed "automatically" (Kahneman, 2003). Categorization of potential stimuli like "membership in a set" is done such that it seems like perceptual discrimination (Gibson & Gibson 1955, cited in Logan, 2002). Even intuition itself has been described as "a perceptual measurement of cues" (Earle, 1972, p. 9). The immediate accessibility of these perceptions may lead to feelings of 100% reliability of the perceptual judgments of the stimuli, similar to the "fully determined environment" that Gibson (1986) references in his description of direct perception. Use of highly practiced activities included in the WIMP repertoire may generate a similar feeling of direct responsiveness to proximal stimuli that may be sufficient in the current context to allow automatic execution to proceed. As with many motor actions, only one conscious evaluation of this match may be needed to initiate the first action in the movement schema (Schmidt, 1987).

Deciding What to Do Next

One contrasting view to Gibson's concept of a "fully determined environment" is Brunswik's view of a "probabilistically determined ecology" (Kirlik, 2001, p. 241). Kirlik proposed a middle ground for these views in which both concepts describe portions of human behavior used within HCI: Gibsonian theory for visually-guided action such as described in the previous section and Brunswikian theory for judgment and decision-making. This third component of intuitive interaction is based on Brunswik's view that that cognitive system must manage with incomplete stimuli. Thus, the essence of this component is determining how the cognitive system "fills in" necessary information to allow intuitive interaction.

Analytical studies have shown that decision-making from incomplete information is generally accurate enough for most functional purposes and may be as accurate as more cognitively intensive calculations. First, the perceptual system is accustomed to concluding in environments with multiple fallible but probabilistic information sources, but expects that environmental factors like cue redundancy help to increase the value of the signal and reduce the effect of this noise (Hammond, 1996; Westcott, 1968). Second, the environment also includes many cues that are not relevant for the decision at hand. As Westcott further explained, the cognitive system, like other information processing systems, only needs a sufficient number of cues to discriminate between the available options. In particular, Gigerenzer (2001) evaluated 20 different studies regarding decision-making in varied environments using a "fast and frugal" heuristic (few discrimination cues) and found that the heuristic provided greater accuracy than more cognitively intense multiple regressions. Lastly, humans make many ordinary decisions such as shopping using a satisficing approach in which the user only investigates enough alternatives to satisfy a threshold of satisfaction rather than trying to maximize their satisfaction level (e.g. McMackin & Slovic, 2000).

The cognitive system actually seems to have neurological mechanisms based on the concept of "filling in" for action selection based on previous experience and expectancies. These mechanisms are similar to feedforward control discussed in Chapter 2. In a recent review of the feedforward paradigm, Basso and Bellardinelli (2006) proposed that this paradigm is the basis for motor and visual control. Feedforward cortical networks develop with experience to represent normal operation of these behavioral systems. They are quite specific to details of the environment such as stimuli orientation and very efficient in managing anticipated timings and dynamics of the action-perception cycles. The goal state for particular actions is represented, and expected inputs can be managed to adjust action parameters to reach this goal state. This process allows feedforward systems to learn without feedback (Tsodyks & Gilbert, 2004). Feedback is still needed to respond to unexpected changes or to evaluate parameters outside of the anticipated controls (Clark, 2000).

These mechanisms suggest a strategic view of feedforward in intuitive HCI in five ways. First, the neural basis for feedforward may allow the general “determining what to do next” in normal operation to feel automatic in the sense of low effort and preconscious selection. Second, anticipation is underscored as an important aspect of efficient human behavior. Anticipating potential responses to an action may prime the user on likely responses so that coincidental stimuli as not interpreted as feedback rather than the true response (Larkin, McDermott, Simon, & Simon, 1980). Correct anticipation may also reinforce the users’ perception that the task is not fully fixed but is predictable, reinforcing their system self-efficacy (Hollnagel, 2002). Third, specific benefits of understanding action-response timings and dynamics go beyond mere anticipation. Orchestrating timing and dynamics of actions and responses such as suggested by the use of rhythm and flow in the Eindhoven team’s research (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004) may provide their own reinforcement for a feedforward processing approach. Fourth, the use of a final state to guide action selection and modification is similar to use of guessing and mental simulation to progress to the final goal (Pirolli, 2006). In behavioral terminology, “crude sketches and tentative statements supply stimuli leading to other sketches and statements, moving toward a final solution state” (Skinner, 1969, p. 152). Fifth, Basso and Bellardinelli (2006) cited Norman & Shallice’s (1986) supervisory attentional control theory as early feedforward thinking, though much of the research on feedforward has been developed beginning in the mid-1990’s.

One critical requirement for the use of feedforward is the presence of a lenient environment in which small errors are expected and allowed, but frequent salient feedback allows learning and progress toward the goal (Hogarth, Gibbs, McKenzie, & Marquis, 1991). As noted earlier, guesses do not have to be exactly correct but only sufficient for rapid hypothesis testing and online correction (Hogarth, 2001). Good labels, consistent layouts, and use of other HCI guidelines allow individuals to predict the result of their actions for reduced evaluation and action planning time. In casual-use systems (such as an Internet shopping site), if users get a new web page that allows them to execute the action expected after successful completion of the prior action, they may interpret this new web page as positive feedback. Users only have to slow down to evaluate and plan if the expected action is not available, the new web page is unfamiliar, or an error message is received. Thus, intuitive usage with this feedforward strategy may not be exactly the same each time even for the same individual. Different users are also likely to interact in unique ways due to individual differences in collecting information and perceiving events (Hollnagel, 2002). Systems with salient constraints that guide users in knowing what will not happen may therefore be the best way for designers to minimize exploration in areas that will not support any potential user goal (Norman, 2002). If users do not see any constraints, they may assume there are not any (Hogarth).

The primary factor influencing users' decisions about what to do next is increasing confidence. This confidence may be based on many factors, including previous experience with the "fill-in" strategy or previous knowledge that guides hypothesis development and evaluation. Confidence seems to be analogous to the guiding index proposed for measuring intuitive decision-making (Bowers, Regehr, Balthazard, and Parker, 1990). This confidence also seems similar to the metacognitive feeling of knowing, guiding users as they connect possible items together and determine how connections suggest a path to the goal (Bastick, 1982). This feeling of knowing may be similar to the feeling of familiarity, which has been shown through psychophysical and fMRI studies to affect object recognition strategies used by the brain (Tsodyks & Gilbert, 2004). In some cases these feelings may thus be perceived as even more salient than real cues in the environment (Kahneman & Frederick, 2002). Though these misperceptions may lead to errors, these feelings have evolved to support processes in which prior knowledge generally protects against substantial disruption in lenient environments. Minor disruptions are tolerated as long as the response is still familiar in the current context and environment, suggesting that path repair can also be made from previous experience. On the other hand, low familiarity seems to be strategically used in selecting analytic processing even in Internet applications due to lack of prior experience (Payne, Richardson, & Howes, 2000). Thus, metacognitive assessments may be used for monitoring use of this intuitive component.

Metacognition

Metacognition is the cognitive faculty through which humans evaluate and monitor their own thinking processes and knowledge content (Hertzog & Hultsch, 2000). The overall question in HCI is determining what action the human should take or will take, the goal of the third sub-section described above that could be monitored by a variable well-studied in metacognitive literature: feeling of knowing (FOK). FOK has been shown to predict judgment accuracy in experiments similar to the intuitive decision-making described earlier (Blake, 1973). FOK judgments have also correlated specifically with intuitive decision-making in experiments that manipulated the reliability of information used in these decisions (Simmons & Nelson, 2006). As noted in the prior section, people seem to heavily weight this metacognitive judgment based on prior experience that it usually signals intuitive accuracy and appropriate use of intuition for selecting an answer. W propose that this metacognitive judgment is used in conjunction with judgments of the “feeling of directness” (from performing well-learned activities) and “feeling of progress” (from seeking user goals) to determine more specifically the cognitive mode used in a particular action selection. We also propose that these judgments are compared against a threshold of action that is set based on the environment and context.

Although “feeling of directness” and “feeling of progress” are not metacognitive judgments discussed in the literature, evidence from general intuitive decision-making and action-perception linkages suggest three reasons that we could think about cognitive operations in this way. First, perceived speed of knowing and judgment is widely cited in the literature as a key attribute of intuitive decision-making (e.g., Hammond, Hamm, Grassia, & Pearson, 1987; Hogarth, 2001). This perception itself may be an important cue for allowing intuitive judgments to proceed. For instance, experimental instructions to operate quickly induce intuitive processing (Earle, 1972). Similarly, decision-latency has been shown to be an effective measurement for intuitive decisions (Sinclair & Ashkanasy 2005). Individuals make quick perceptual discriminations if available decision time and accuracy requirements are low (Goldstone, 1998).

Second, characteristics of automatic processing can be systematically analyzed by the cognitive system, though the speed of automatic processing suggests that the decision to invoke automatic processing must operate very quickly. Logan’s instance theory (Logan, 2002) proposed one mathematical model that explain how this could happen, but the important question is whether automatic processing of well-learned activities can be sufficient or whether additional cognitive processing (such as hypothesis generation or fill-in) is needed. As suggested by Kirlik’s (1995; 1998) proposal that individuals try to simplify processing by making distal variables available through proximal variables, the question could be rephrased as assessing how directly the stimuli is perceived. If perceptions appear to be 100% reliable and action schemas exist to use the stimuli efficiently (see Schmidt 1987), the metacognitive system may decide that automatic processing is the most efficient approach. Supporting this idea, Simmons and Nelson (2006) found that beliefs held with certainty were experienced as percepts, easily accessible, and difficult to change. We therefore use the term “feeling of directness” to capture the metacognitive measurements for describing how well-learned activities are initiated and governed within intuitive interactions.

Third, FOK should operate in a dynamic process for intuitive interactions as shown in

Hamm's (1988) dynamic decision-making case studies. Decisions and actions available at time *t* are dependent on actions taken at (*t*-1) and affect what actions will be available at (*t*+1). FOKs could perhaps be similarly captured at each interval and summed for a metacognitive judgment about whether actions are proceeding toward a goal. For abstract or unknown goals (in an exploratory environment), the judgment might be whether the environment is proceeding toward coherence or increased familiarity. As described earlier, this idea was initiated in intuitive decision-making research as a guiding index (Bowers, Regehr, Balthazard, & Parker, 1990), but we use the term "feeling of progress" to parallel other measurements and suggest metacognitive usage.

Thus, metacognitive judgments about feeling of knowing that govern intuitive interactions are mediated by feelings of directness and feelings of progress. Feeling of knowing is critical because it provides information about whether there is any internal knowledge that might guide behavior or whether analytical processing must be used to systematically interpret information in the environment. The feeling of knowing must be interpreted in context, though. Feelings of knowing or familiarity seem to increase accessibility judgments like the feeling of directness (Kahneman, 2003). If the feeling of directness is not high enough to suggest complete reliability given the context, however, the feeling of knowing will be used for hypothesis testing or selecting fill-in strategies. If the feeling of directness is artificially high because a system display presents cues as though they are completely reliable and comprehensive (as demonstrated in the first automation experiment by Horrey, Wickens, Strauss, Kirlik, & Steward, 2006), users may incorrectly not use fill-in strategies to assess correct actions. Thus, these three judgments do not seem to operate independently of each other in intuitive behavior. Behavior that is well-learned and goal-oriented is merely automated behavior. Well-learned behavior that is based on random guesses with no goal in mind is more like wandering around. Determining what to do next with a particular goal in mind but no use of well-learned behavior requires more cognitive effort and time than would be suggested by intuitive behavior. All three activities of the organizational framework shown in Figure 6 are thus necessary for intuitive HCI.

There remains the question of how intermediate predictions and guesses might be used in actually initiating interactive behavior. We propose that a fourth metacognitive variable, action threshold (AT), is used in a manner similar to Simtonton's (1980) threshold for behavior proposed for intuitive vs. analytic decision-making. The AT may be set according to several different factors. For instance, Schmidt (1987) proposes that an individual's disposition affects the threshold settings because tired, bored, or lazy individuals want to allocate minimal resources to managing behavior. Todd and Gigerenzer (2007) also demonstrated that specific judgment heuristics can improve decision-making accuracy because the heuristics incorporate environmental cues about cue reliability. Instructions about accuracy or time availability may also influence the AT. A more specific proposal for how this AT may be used with the three component variables will be discussed in Chapter 6.

Knowledge in the Head and Knowledge in the World

An additional benefit of understanding how these metacognitive judgments affect intuitive interaction is predicting how users may select knowledge to use in interactions. In his influential book, *The Design of Everyday* Things, Norman (2002) recommended that users have two major sources of knowledge: knowledge in the head encompassing previous information implicitly and explicitly learned and knowledge in the world encompassing system features and environmental information available for particular interactions. He proposed that designers could improve user performance by mapping knowledge in the world (determined by system design) to expected knowledge in the head. Blackler (2006) essentially confirmed this recommendation through her more detailed continuum of knowledge in user's heads that could be accessed by designers. As discussed in the critique of Blackler's research in Chapter 4, however, her research does not identify why different knowledge is used by different users but that this identification is very important for effective design. In fact, there could be environments in which performance could be more accurate if uses did not use knowledge in their head such as warning labels for vaguely familiar products (Adams, 2006). Ideally, metacognitive assessment should provide appropriate guidance, but knowledge in the world may be misinterpreted or misused if is not designed correctly.

An example scenario may clarify this proposition. Designers may assume that user selections are guided by labels (knowledge in the world) when in fact they are guided by prior experience (knowledge in the head). Specifically, several research studies have found that icon location is frequently the most salient cue for guiding visual search on a web page (e.g., Beck, Peterson, & Vomela, 2006; Ehret, 2002). According to the visual search research, users store icon location in retrospective memory as part of scan path control to help them remember what they examined. If an icon is moved after examination, scanning is slowed when users return to the icon in the new location because they are not sure it has been examined (Beck, Peterson, & Vomela). Similarly, well-learned buttons and menu options are learned by general location, and access by location is supported as long as the feeling of familiarity is sufficient (Payne, Richardson, & Howes, 2000). When familiarity is lower, users weight location less heavily and may expect to read labels to find an option. If familiarity is high but options are moved, however, users may be frustrated trying to use prior location knowledge instead of the new label information provided on the interface display.

For the normal, online control cases, however, the selection of knowledge in the head and knowledge in the world is governed by usage in prior experience. As web navigation is generally executed by practiced users, for instance, users have specific expectations about what knowledge in the world must be retrieved for the current process and when knowledge in the head is sufficient based on cost/benefit strategies (Gray & Fu, 2004). The loose constraints established on many web sites, however, has allowed individuals to develop variations in execution of common functions, which may differ sufficiently to cause problems for individuals “trained” by non-optimal web sites (Gray, 2006). Protecting the user from dangerous functions and ensuring that they finish their tasks, therefore, is most effective when designers use attentional-control strategies such as timing, saliency, and prescriptive communications (M.D. Byrne, personal communication, October 10, 2007).

Review of Framework and Proposed Definition

From the literature review, an organizational framework for understanding intuitive HCI was created with six key components. First, users' behavior is oriented toward achieving functional or subjective goals, including finding coherence in a novel domain. Second, feedforward methods allow activity selection based on hypothesis-testing/fill-in strategies that progress toward goal with quick, preconscious evaluation of response to each action and online correction. Third, well-learned activities are frequently used within intuitive interactions because they are perceived to be direct and appropriate for the current environment and context. Fourth, metacognitive judgments are used in lenient environments to efficiently determine how to use each component by combining feelings of knowing, directness, and progress toward goal. Fifth, environmental and context effects are delivered to the judgment process through an action threshold. Lastly, the judgment uses a combination of knowledge in the head and knowledge in the world as dictated by the action threshold and component selected. The framework also shows that intuitive interactions are inherently dynamic, so it is unsurprising that periods of analytic activity may be found within generally intuitive interactions.

This framework can be summarized into a working definition for intuitive HCI: *interactions between humans and high technology in lenient learning environments that allow the human to use a combination of prior experience and feedforward methods to achieve functional and abstract goals.* Given that this definition and the framework are still inherently conceptual, it could still be difficult for designers and computer professionals to create intuitive technologies. Thus, the next chapter will translate these conceptual outputs into tools more familiar in technology development to facilitate use by the target professionals.

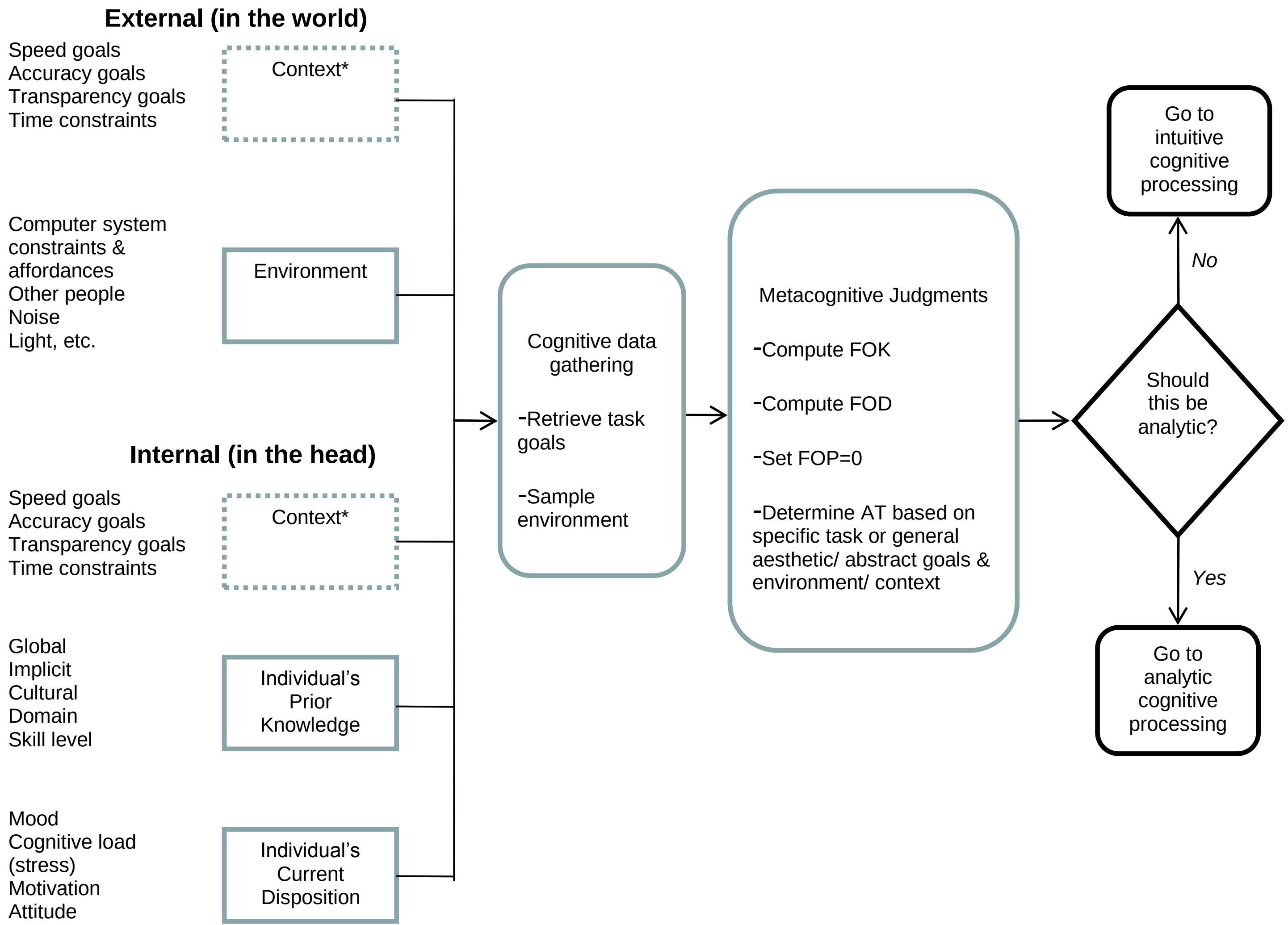
CHAPTER 6: PROPOSED USE AND MEASUREMENT OF HCI

Introduction

The purpose of this chapter is to interpret the organizational framework proposed in Chapter 5 for computer systems professionals and designers so this framework can inform their user-centric design approach. We first describe intuitive user interactions using a workflow approach that is more similar to other systems design tools than a conceptual framework. Then, we describe the requirement and evaluation guidelines that could fit within a typical systems development lifecycle as shown in Figure 1.

Flow of Intuitive Interaction

As Hamm (1988) found in his study of dynamic decision-making, many of our normal actions do not operate purely in one cognitive mode or the other, but there are characteristic alterations throughout. The specific patterns of behavior for intuitive use have been little explored, though empirical examination of appropriate data captured during intuitive and analytic interactions should elicit possible patterns. Before examining the overall patterns, it is useful to understand how the framework might be used in simple interactions. Three diagrams will be used to describe intuitive (vs. analytic) effects in intuitive interactions. Figure 9 shows overall interaction initiation, with example internal and external factors shown as inputs to the interaction that continues in the next diagram. Figure 10 then shows how analytic and intuitive processing are completed as guided by metacognitive judgments. Lastly, Figure 11 shows how the successive metacognitive judgments are used in comparison to the action threshold.



**Note that internal and external context may not be the same*

Figure 9. Overall Human-Computer Interaction.

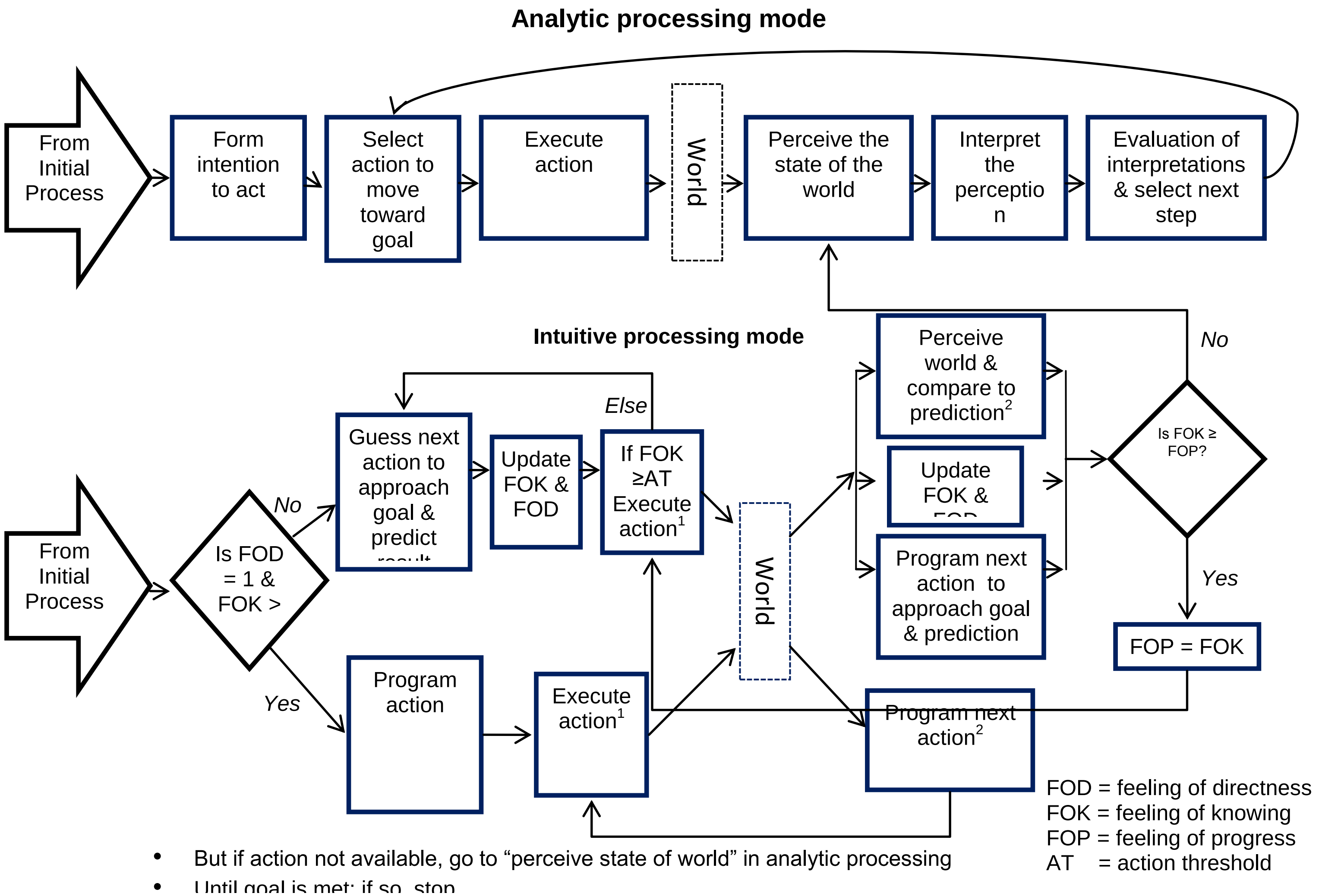
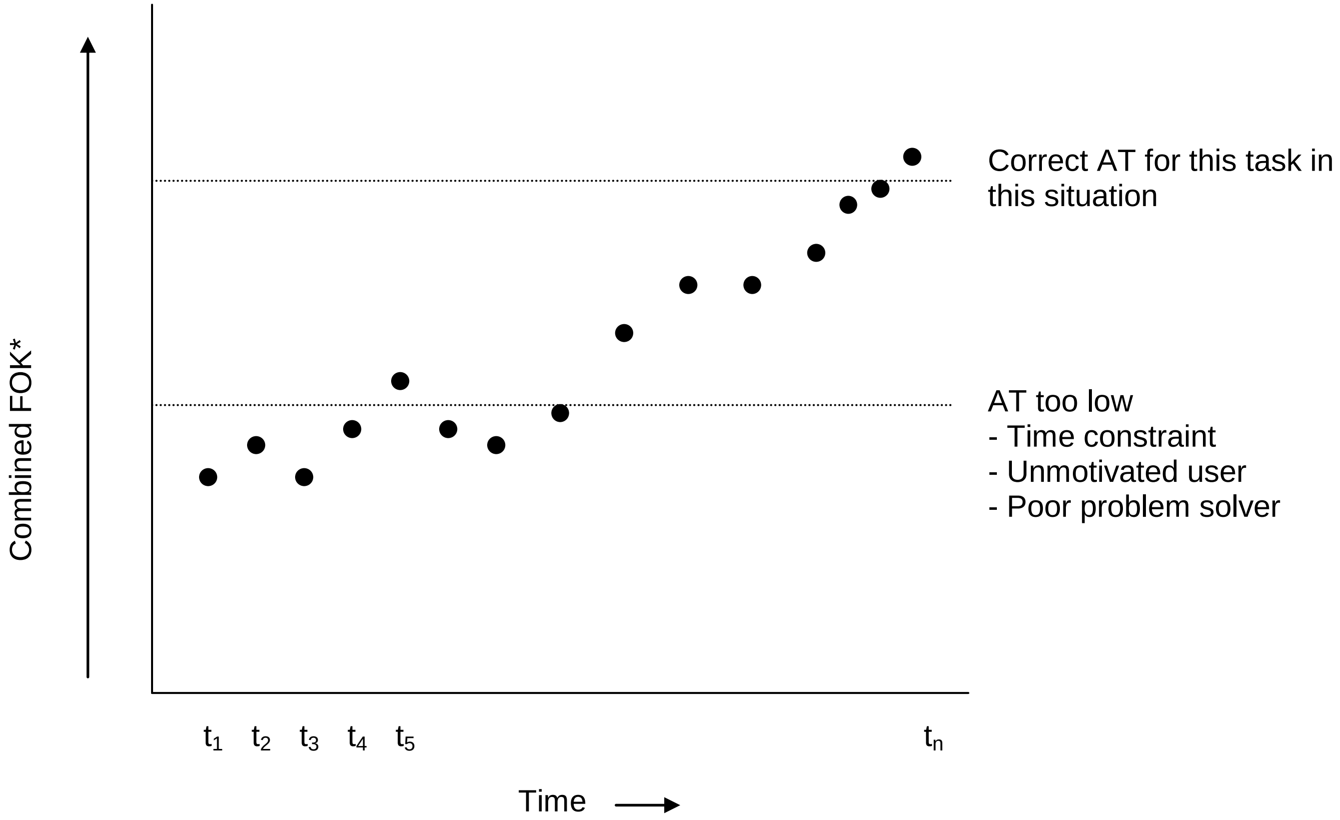


Figure 10. Proposed Analytic and Intuitive dynamic processing.



FOD = feeling of directness
FOK = feeling of knowing
FOP = feeling of progress
AT = action threshold

* Mediated by FOD, and proximity to goal

Figure 11. Proposed metacognitive effects on intuitive behavior.

Figure 9 begins with factors typically shown in interactive behavior diagrams. Note that this diagram has split up factors previously combined to highlight factors identified as important for intuitive decision-making even not been tested in HCI. For example, Sinclair and Ashkanasy (2005) summarize research on emotional effects on decision-making (i.e., positive mode induces heuristic use, negative mood induces analysis), though a preliminary review of HCI literature did not uncover any studies confirming that these effects extended to intuitive HCI. Similarly, context is split between internal and external factors because though experimenters may wish to control these factors with specific instructions, participants' bring their own experience that may affect how they interpret these instructions in light of the stimuli.

The first step in the flow is to gather specific data for the metacognitive faculty. Then, the metacognitive judgments of FOK and feeling of directness (FOD) are calculated based on the environment and prior knowledge. The feeling of progress (FOP) is set to 0 as we assume that the goal is not reached at this point. The action threshold (AT) is set to reflect a level for which current motivation and prior experience suggests that goal should be met given the current environment and context. The most important output of this initial judgment is determining whether the analytic processing mode is most appropriate for this aspect of the task, and the next section of this chapter will discuss factors to be considered in this judgment. Otherwise, intuitive processing will be used (as the default mode).

Figure 10 is based on Norman's (2002) Seven Stages of Action, with the analytic processing mode mapped almost directly onto these stages. The intuitive processing mode incorporates both true intuitive interaction (top portion of this flow) and the "performing well-learned activities" (bottom flow). Because the latter is simpler, we describe this mode first.

As described in Chapter 5, "performing well-learned activities" is very efficient and effective in the right situations, so the metacognitive processing faculties assess if these attributes exist by evaluating if the perceptions are 100% reliable (FOD) and the situation supports this mode (AT). If both conditions are met, the performance of this activity will proceed until the activity end is met, unless there is an error that requires diagnosis and repair or unless the next action in the activity sequence cannot be performed. In either case, processing is interrupted and evaluation performed in the analytic mode. This mode is not exactly the same as automatic processing (as defined in Schneider, Dumais, & Shiffrin, 1984) where presentation of a stimuli immediately triggers a response, with limited ability for response inhibition. Instead, this mode is better explained by models of highly practiced motor skills (see Schmidt, 1987, for a description).

The "true" intuitive processing mode appears to be more complex because of the iterations and metacognitive assessments, but cognitive effort is not much higher than "performing well-learned activities". This flow is derived from the theory of easily learned interfaces (Polson & Lewis, 1990), but adding the metacognitive judgments that support the ideas proposed in that theory. The negative response to the questions posed above (i.e. ($FOD \neq 1$) and/or ($FOK \leq AT$)) suggest that hypothesis-testing/fill-strategies must be used to determine the appropriate next action. As discussed with label-following (in the theory of easily learned interfaces) and feedforward ("deciding what to do next" section in Chapter 5), hypotheses are selected to decrease distance to the goal. Knowledge of the goal (or at least a perception of the goal as discussed in the "seeking user goals" section of Chapter 5) allows low-effort online correction. FOK is then updated to reflect the potential for approaching goal and ability to execute the action. If the proposed action does not appear viable or likely to decrease distance to the goal, alternative hypotheses/fill-in strategies will be used to guess other potential actions in a manner similar to the hill-climbing strategy (in the theory of easily learned interfaces). The perceived complexity of this is reduced because this strategy is efficient from frequent use, but the real savings for intuitive processing comes from evaluation process.

Evaluation of expected responses may be faster than analytic evaluations because the expected item is primed in the visual system for faster recognition (Barsalou, 2003). In addition, the focal attention may proceed to the next attended item for processing while peripheral attention confirms presentation of expected response (Beck, Peterson, & Vomela, 2006). Thus, the three actions on the diagram listed horizontally after “world” (i.e., Perceive world and compare to prediction; update FOK and FOD; and Program next action) can be executed in parallel. Then, the metacognitive judgment (FOK $\geq$FOP) is made, perhaps within a set of parameters depending on AT, is made to determine if the behavior is progressing toward the goal. If it is, FOP will be updated to maintain the value of this progress. If progress is not being made, cognitive processing may shift to the analytic mode for a systematic evaluation and consideration of other options. This shift may also occur in the case of errors or unavailability of proposed actions. Generally, though, this interactive flow will continue until the goal is reached.

Figure 11 shows a proposed way that metacognitive judgments could affect intuitive behavior. This diagram has been created to show a set of decisions that reflect iterations of the guess/action cycle shown in the intuitive flow in Figure 10. A time frame is shown along the *x* axis to reflect the dynamic nature of these decisions, but the reality that each action selection represents a decision. The combined FOK (FOK mediated by FOD and FOP) is shown along the *y* axis to reflect the FOK at the point of each action selection. Note that combined FOK is fluctuating in a small range in the early stages, perhaps as the user assesses what information might be available on the web site to answer a particular question. If their threshold was set too low (lower line in the diagram), the conclusion made at time t_5 could be incorrect as discussed in Westcott’s (1961) studies about individual differences in use of confidence factors in decision-making. The individual should instead be continuing to withhold a final judgment about a solution until the confidence reaches the higher (correct) threshold. Note that the increases, decreases, and levels of change also affect the guesses themselves and help to guide progress to the goal. For intuitive interactions, we would expect to see oscillations of FOK like this within groups of activities that individually achieve subgoals, though ultimately these subgoals should converge toward the overall goal.

One challenge to this framework is that it does not fit the analytic-intuitive continuum with each mode proposed as a pole with quasi-rationality in the middle of these poles (e.g., Simonton, 1980; Hammond, Hamm, Grassia, & Pearson, 1987). We would suggest instead that this framework explains the continuum more clearly by identifying mechanisms that determine the alterations and general patterns specified by Hamm's (1988) case study. Though only briefly mentioned in this framework, characteristics and functions for the analytic mode described in the continuum research are similar to the behavior we classify as analytic in the requirements section, below. On the other pole, we also suggest that characteristics proposed for intuitive behavior are similar to what we propose exist *at high FOK* in intuitive interactions. Most of the time, however, individuals operate at lower levels of FOK, in environments with AT levels that allow them to hypothesis test as they as they progress toward a goal. For instance, an eye movement study found that scanning is cheap in WIMP environments, and individuals scan the display repeatedly with increased focus on increasingly limited number of items until one is selected (Rieman, Young, & Howes, 1996). Thus, exploring a display with a mouse and visual scan may be similar to the quasi-rational approach described in continuum research.

Requirements

To support user-centric design, the first task for which an understanding of intuitive interaction is helpful is the requirements analysis (first shaded box in the bottom row in Figure 1). As shown above in the overall human-computer interaction (Figure 9), the first related decision about interactions is determining whether the interaction should be analytic. This decision is supported by decision-making and cognitive engineering researchers claiming specific functional roles for the analytic or system 2 (e.g., Degani, Shafto, & Kirlik, 2006; Kahneman & Frederick, 2002; Sloman, 1996) cognitive modes. Thus, developers should first analyze the specific reasons for which analytic processing should be the correct mode.

One analytic tool is a list of characteristics inducing analytic (vs. intuitive) processing in Table 1. This table allows developers to examine questions about proposed design such as:

What kind of cues will individuals be examining? Objective, reliable measurement cues may require focal examination for users to discriminate differences between values. Multiple shapes on a screen that are more subtle discriminated may also encourage analytic processing.

What cue redundancy will be on the interface? Recall that cue redundancy allows users to guess more accurately because it reduces the number of possible solutions that incorporate all cues. With low redundancy, however, the analytic processing mode allows individuals to make individual, sequential decisions to reach the goal.

Can a task be cleanly decomposed into discrete steps? If there is only one path for all users (or even the majority of users) to get from start to goal and users complete the task intermittently (such as airline check-in stations), better performance may be obtained by guiding users through this process in an easy-to-use manner than trying to deliver intuitive use. The step-by-step approach has been found to elicit analytic processing (Baylor, 2001).

Will cues be displayed simultaneously or sequentially? Simultaneous display of cues invites pattern matching which can be extremely quick and effective if users have extensive domain knowledge (as experienced fire commands have shown with recognition-primed decision-making (Klein, 1997). Sequential display of cues, however, invites systematic consideration of the available cues.

Additional questions are suggested by considering the cognitive processes themselves such as shown in Table 2. Particularly to elicit analytic processing, developers should consider:

Should users be reliably and systematically using cues in the same way? Analytic processing promotes high cognitive control by providing sufficient time for users to apply rules in a consistent fashion. Intuitive processing promotes low cognitive control whereby multiple paths for reaching a goal from the same start are possible. Developers may specifically want to prevent this multiple path approach in business environments where the desire for transparency is high, though an experimental study trying to invoke analytical processing based on transparency and accountancy instructions (among auditors) found no statistical significance (Henderson, 1999).

Should users be aware of their cognitive activity? The cognitive efficiency of intuitive processing encourages users to think about future action rather than current action. Though this is effective for open-ended systems exploration, it discourages users from mentally recording steps they have taken. This may be adequate for normal operation, but automation must provide this information to help orientation and diagnosis if problems occur (Flach, 1995).

How much time will be available for processing? User instructions to take their time with adequate tool support invoked analytic processing tasks that could be interpreted as intuitive with instructions for quick operation (e.g., Earle, 1972).

What metaphors will be used? As discussed in chapter 3, metaphors may have limited usefulness in transferring knowledge to new systems. If they are used, however, selecting the appropriate type of metaphor communicates at a broad level what type of cognitive mode should be used. Thus, information presentation in verbal, quantitative methods such as tables has been shown to elicit analytic processing (Henderson, 1999).

As requirements for analytic processing are completed, developers can consider how to optimize design for intuitive processing. The factors identified in discussion of the intuitive processing framework suggest several questions and recommendations for improved intuitive performance, including:

In what cases should people use knowledge in the world rather than knowledge in their heads? It would seem that the answer to this question is obvious: when the knowledge in the world is more reliable. As described in this paper, however, intuitive interaction elicits behavior in which individuals may fluctuate between using knowledge in the world vs. knowledge in the head depending on costs and benefits of accessing each type of information (e.g., Gray & Fu, 2004). If systems are designed to be easy-to-use, individuals may implicitly learn aspects of systems use that decrease the cost of using knowledge in the head. Users may then be unaware that information on the display has changed that should replace their use of knowledge in the head. Further research may be needed to understand how design can affect knowledge selection.

In intuitive systems with automated functions, how will users know that automation is providing only a subset of information that may limit problem diagnosis and repair? This problem is similar to the framing problem described in general decision-making literature (e.g., Tversky & Kahneman, 1971), though it has been separately discussed as an automation problem for over a decade (Flach, 1995; Norman 1990). The general recommendation is for automation to “observe” and “remark” on ongoing progress to build situation awareness and increase the opportunity for intervention if needed. Otherwise, users can be completely surprised by problems, immediately reducing their feeling of familiarity to 0 in an environment with hidden status and prior event knowledge that makes even analytic processing difficult to succeed.

Help users conclude about system boundaries with clear constraints: Prevent users from wandering into areas that they will never want to enter or the system owner will never want them to enter with hard constraints on these activities (Beale, 2007).

Lead users with proposed goal and flow: For novice and intermittent users in systems designed to facilitate specific functional goals, users may be more satisfied if their interactions are guided by using controls with natural functions, clear coupling of action and response, and creative use of feedforward (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004). If the system is analogous to another system, understand what cues allow an individual to recognize this analogy and provide these cues to let the feeling of familiarity guide them to make this connection. Use echoing and repetition to reinforce the direction of the flow and linkage with other elements/ functions relevant for the same task goal (Barsalou, 2003).

Manage expectations with feedforward: Individuals can only use the simplified response evaluation process of intuitive processing if responses are expected (Wickens & Carswell, 1997). Thus, designers can facilitate simpler processing by suggesting expected results of actions. These can be subtle so that they are used as needed, particularly with peripheral vision (Spool, 2005).

Communicate clearly that error consequences/costs are low. The user should be aware that this is a lenient but learning environment (Hogarth, 2001; Kahneman & Frederick, 2002). In web-based systems, the major cost is that the user will lose time from errors but can just return the same way they came.

Support user needs for interaction and manipulation of environment to improve access to distal information and resolve ambiguities: Research has shown that user actions and experimentation allow them to perceive knowledge even in impoverished environments more effectively (e.g., Flach, 1995; Kirlik, 1998). For systems in which users will gain significant experience even through implicit learning, designers should provide users with controls that allow them to gather information in ways that make sense to them, even if based on idiosyncratic prior knowledge.

Provide diagnostic feedback user to reduce evaluation time and need for analytic processing: Intuitive systems work well in normal operation, but they cannot manage error correction well (see "Determining what to do next" discussion in Chapter 5). When errors are made (expected due to environmental leniency), researchers recommend that feedback is frequent, fast, and diagnostic (Hogarth, 2001). Though users use analytic processing to recover, they experience minimal time loss or frustration because they know exactly what to do. They may then be unlikely to adjust the AT to guard against errors and can return to intuitive processing.

When the development cycle moves from the requirements phase to the design concepts phase (see Figure 1), developers should consider more specific design tools. There are many guidelines for general ease of use as described in the HCI guidelines section of Chapter 4, but recommended designs for intuitive use are limited. As described at the end of Chapter 4, Blackler and colleagues and the IUUI team have proposed tools that may be useful. In particular, their knowledge continua provide a systematic approach for selecting the appropriate user knowledge to leverage, though requirements outlined above should be considered in facilitating user selection of that knowledge. The image schemas being developed by the IUUI team (Blackler & Hurtienne, 2007) may also be useful, though a focus on individual features rather than guided use may lead the design community only to improved HCI guidelines rather than specific approaches for creating intuitive technology.

Behavioral scientists should also consider the impact of these findings on experimental design. Differential effects of familiarity between participant groups, for instance, may induce intuitive processing in one group and analytic processing in the other (Kahneman & Frederick, 2002). Individuals experiencing particularly high levels of positive or negative affect may be either more likely to use intuitive processing or analytic processing to correspond with their affect (Sinclair & Ashkanasy 2005). Affect may also induce differential task execution because analytic processing is more affected by instructions than intuitive processing (Kahneman, 2003). Extrapolating from Tables 2 and 4, experimental instructions that are detailed and include verbal or quantitative stimuli may elicit analytical processing. On the other hand, instructions that encourage users to decide quickly, not worry about errors, and use their own experience may elicit intuitive processing. Lastly, the use of between participant designs in decision-making experiments may mitigate unanticipated effects of each condition (Kahneman & Frederick).

Evaluating Usage

As described in Chapter 4, the previous method for identifying intuitive decision-making/action selection was coding think-aloud segments as intuitive because on response on speed and lack of verbalized reason for response (e.g., Blackler, Popovic, & Mahar, 2003b; Hamm, 1988). As described particularly in the critique of Blackler and colleagues' methodology, this method is limited. Instead, we propose two types of measurements may provide converging evidence for intuitive processing using objective and subjective tools. Note that research will be described supporting why they may be useful for identification of intuitive patterns, but these measurements have not been empirically tested for this purpose.

Objective measures could be based on computer mouse patterns, including: click rates, click intervals, click resting rates (pauses), page changes, and page backups. Three patterns of behavior have been found in the literature that may emerge for intuitive behavior. First, oscillating patterns of behavior (similar to Hamm, 1988) with lower click rates and more pauses in the beginning are expected as users assess the environment, but bursts of activity with low variability between clicks are expected as users identify particular goals that can be achieved though intuitive and well-learned behavior. Based on the hypothesis that well-learned behavior is similar to automatic processing, consistent responding is expected for this behavior (Schneider, Dumais, & Shiffrin, 1984). Truly intuitive behavior would be more inconsistent, but latency between clicks should decrease as feelings of familiarity increase with progress toward a goal.

Second, patterns of intuitive and well-learned behavior are expected to change with practice. These patterns may demonstrate that intuitive HCI is similar to problem-solving whereby activities are chunked to correspond with subgoals within a broader problem space. In the system domain, pauses between mouse clicks may be similar to the head-turns Chi (2006) measured to assess knowledge chunks for chess novices and experts. Evaluating these might reveal that pause times are consistent but that the number of activities between pauses changes with practice. Alternatively, patterns may be more similar to information foraging with one pattern of click rates and latencies “between patches”, but a different pattern “within patches” (Pirolli & Card, 1999).

Third, different behavior patterns are expected when users are operating correctly vs. incorrectly in intuitive vs analytic processing modes. For example, when users are confident of the next step but select it incorrectly during intuitive processing, they should quickly backup to the prior step and proceed forward with little change in click rates and continued progress toward the goal. This may be similar to online correction described in the feedforward section of Chapter 5 whereby the anticipation of the goal (or subgoal) itself maintains momentum. If the same error had happened during analytic processing, however, users are likely to analyze the system response more thoroughly. Thus, additional pause times would be expected in analytic mode. This pattern may also be visible from a trace that tracks an individual's path of clicks and page changes (Djajadiningrat, Wensveen, Frens, & Overbeeke, 2004).

These patterns can be compared with three subjective measures: self-ratings, metacognitive judgments and coding of thinkaloud statements. Self-ratings can be obtained by asking the user to rate system intuitiveness on a Likert scale at designated points during web navigation. Metacognitive judgments of feeling of knowing can be captured by having the user record or say how confident they are in their current position to reach the goal, similar to the approach in other experiments using this measure (e.g., Koriat, Ben-Zur, & Nussbaum, 1990). With the thinkaloud method, users are instructed to think aloud as they navigate the web site and comments are recorded for later analysis. Alternatively, self-explanation effects on behavior may be reduced if users navigate the web site silently while the behavior is videotaped. Afterwards, users review their own behavior and provide thinkaloud commentary (Howie, 1998). Coding protocols from Hamm (1988) or Blackler, Popovic, & Mahar (2003b) can be used to identify intuitive and analytic system uses from either thinkaloud method.

Overall comparisons should be made between the sets of measures to validate the effectiveness of the different methods, though it may take several rounds of testing to identify specific points at which subjective measures should be taken. In addition, examination of these measures can help to identify effects of practice as well as similarities between and within individual users. Identification of patterns that are consistent among users at particular parts of the flow may be particularly helpful for confirming that the proposed requirements for eliciting intuitive vs. analytic usage (in the previous section) are correct.

Summary of Tools for Professional Use

This chapter organizes information from prior chapters to answer the primary goal of this paper: helping technology designers to elicit and improve intuitive system usage when this characteristic is targeted for their product. Recommendations to meet this goal are provided in three tools. First, the workflows provide templates for walking through high-level planning sessions on the new product. Second, the requirements guidelines provide specific questions that can be analyzed to define more clearly the type of behavior that should be used and how behavior will be governed in this product. Third, objective and subjective evaluation techniques may be used in conjunction with typical usability testing to confirm that the correct modes are used at the points designated in the systems requirements. These techniques may also help resolve specific decisions between alternative designs based on the type of behavior elicited. More research is needed, however, to specify the expected patterns of mouse clicks, pauses, etc. for matching with intuitive vs. analytic behavior patterns.

CHAPTER 7: CONCLUSION

Introduction

The purpose of this paper was to create a definition and framework for intuitive HCI. One practical output of this research was to help technology designers meet the attractive but elusive goal of creating intuitive technologies. By helping designers understand how intuitive technologies work, our goal was also to provide additional direction for creating technologies that are not only easy to use, but also elicit changed behavior. Our review first examined relevant literature to develop a top-down understanding of intuition and intuitive decision-making (similar to action selection with technologies). Then, we examined research on novice computer interactions and HCI guidelines/design to compare these bottom-up perspectives on natural user interaction with the top-down understanding of intuitive behavior. From these reviews, we created a framework and definition of intuitive HCI that can be useful for educating technology designers as well as researchers investigating other avenues of intuitive behavior.

Key Findings

Overall, our review of the literature on intuition and intuitive decision-making found that many factors considered in comprehensive reviews (e.g., Bastick, 1982) and empirical studies of decision-making (e.g., Hammond, Hamm, Grassia, & Pearson, 1987) are very relevant for intuitive HCI. In particular, the biggest issue for designers to consider is that intuitive processing is the default mode of operation. Thus, they need to understand this processing mode so that they can predict and guide effective interactions. They also need to identify when intuitive interaction is inappropriate so that they can induce and guide effective analytic interactions instead.

Another important finding was that though HCI guidelines included many of the intuitive factors identified the top-down review, the guidelines only framed general usability and ease of use. Guidelines and best practices for governing behavior in a lenient environment and for priming users to select the best options are emerging, but they do not seem oriented to include subjective factors of use of confidence and emotional involvement that may be critical for promoting exploratory behavior that leads to new usages. Thus, ease of use seems to be a necessary but not sufficient component of intuitive technologies.

Based on literature review even outside of the core intuition domains, particularly in cognitive engineering and management decision-making, we proposed a working definition for intuitive HCI: *interactions between humans and high technology in lenient learning environments that allow the human to use a combination of prior experience and feedforward methods to achieve their functional and abstract goals*. We also created an organizational framework of intuitive HCI to illustrate the core components of intuitive HCI. This framework is presented in Figure 8, with each component described briefly below:

Seeking user goals: User behavior is oriented toward achieving goals that may be concrete and functional like completing a specific task. The goals could also be more abstract and subjective like beauty, truth, or pleasure. A general goal of finding coherence in an environment being explored may also guide behavior and motivate perseverance as the user seeks a sense of completion from their activities.

Performing well-learned behavior: Users select cognitively efficient, well-learned processes if they are immediately accessible and unconsciously judged to be appropriate for the current environment and context.

Deciding what to do next: If prior experience suggests that available cues are incomplete or unreliable and the current context is lenient for learning, use prior knowledge to suggest possible next actions. Users may mentally simulate possible outcomes of each action, using peripheral knowledge and distant associations to help them evaluate and select the next action. Online correction is provided through feedforward methods. This activity itself is well-learned and can be done with little effort or conscious attention.

Metacognition: Use the combined feelings of progress (from selected goal and progress toward goal), directness (accessibility of well-learned activity as well as perception of external information to be used), and familiarity (of proposed actions, knowledge, and simulation/fill-in techniques for this type of interaction) to select the cognitive mode and knowledge that will be used.

Knowledge in the head: Norman's (2002) book identifies this as the user's global, implicit, cultural, domain and ability knowledge they bring to the task. This was described earlier as influenced by prior experience.

Knowledge in the world: Norman's (2002) book identified this as information in the environment including computer and other stimuli. This includes the environment and task context.

Of course, this framework must be validated empirically, but conceptual validation was completed by creating three tools that could be used by technology designers to create intuitive technologies. Discussions of two of the tools, a workflow and the requirements guidelines, included presentation of other research that was consistent with the proposed framework. The brief summary of impacts on experimental design that might be affected by differences between intuitive and non-intuitive processing was also based on the framework and prior research. The proposed evaluation techniques, however, are based on existing techniques but allow specific data gathering and assessment that will provide one approach for validating the framework. If the overall framework and definition are proven or modified, a systematic review of the guidelines should be completed and compared with a comprehensive set of HCI guidelines and best practices to evaluate overlap, determine if guidelines are missing, and identify those guidelines and practices that facilitate intuitive behavior.

Research Gaps

As described above, the most important research need is to validate the framework and working definition of intuitive HCI. This validation can start with the evaluation of expected patterns of interactive behavior between intuitive and non-intuitive systems. Although Chapter 6 discussed several possible high-level patterns, it may be necessary to understand patterns of the feedforward mechanisms in the motor and visual systems in greater detail to identify common factors. Feedforward as described in control theory (e.g. Jagacinski & Flach, 2003) may also suggest potential patterns of behavior. There may also be relevant HCI research on mouse click evaluations to identify problem-solving or decision-making patterns.

A second important aspect of the component model is the role of metacognition in intuitive interactions. Although empirical studies have linked feelings of familiarity and confidence to intuitive processing, the proposed feelings of directness and progress are merely speculations based on gaps in the literature suggesting that these cues might exist and provide the functionality for the processing flow to happen as proposed. These latter feelings may not even be metacognitive judgments, but perhaps are perceptual discriminations dependent on other judgments such as described by Brunswik's Lens Model (Brunswik, 1955). For the purposes of subjective evaluation of these metacognitive judgments, other techniques besides instructed questions about feeling of knowing, for instance, should also be tested. Additionally, social cognition research should be reviewed evaluate how emotions and familiarity are used in human-human communications to propose mechanisms for use in human-computer interaction.

Thirdly, the intuitive interaction design research currently in progress (Blackler and colleagues; IUUI team) have developed tools to organize user knowledge that may be utilized in technology interactions. These tools can guide systematic review of possible sources of knowledge for a target user group, but theoretical foundations that govern how users determine which prior knowledge to tap for a particular system are not applied. In the same way that psychological research on attention has directed refinement of HCI guidelines on presenting knowledge in the world (e.g., cue salience, cue redundancy), application of knowledge retrieval research could similarly direct development of more specific knowledge selection guidelines.

Lastly, examining individual differences in intuitive HCI may reveal generalizable conditions affecting intuitive behavior. For instance, Freudenthal (1999) discusses how differences in the age of knowledge acquisition may explain usage differences between younger and older adults. A theoretical explanation for this difference was not given, however, so one can only speculate if typical declines due to aging (e.g., decreased working memory, decreased fluid intelligence) lead users to prefer accessing knowledge in the head vs. trying to encode knowledge from the world? Alternatively, has overall experience suggested that knowledge in the head is more reliable because of typical limitations in the reliability of perceptual information? If the latter is the case, are all users more likely to rely on previous knowledge in noisy or perceptually-limited environments? Thus, theoretical knowledge can be advanced through investigation of areas originally defined as applied psychological research.

Final Implications

In conclusion, we recommend that more HCI programs of research are directed at understanding and specifying ways to deliver intuitive interaction. The course set by marketing professionals is worth pursuing for achieving design that is truly human-centric because it allows people to meet known goals and uncover new goals. This approach will be particularly important to facilitate acceptance of ubiquitous technologies that will introduce dramatically different mechanisms for human-technology interaction.

These findings should also be disseminated back to disciplines that have seeded this research, particularly management decision-making, to further examine the proposed larger role for metacognition and to understand how feedforward might work in different domains. The suggested psychological research to validate and refine the intuitive HCI framework may also reveal better methods for investigating these mechanisms even outside of HCI. Thus, although this paper was originally prepared to investigate approaches for applying psychological research in one specific domain, the results of this review can renew and integrate theoretical research from contributing areas for further cross-pollination.

REFERENCES

The American Heritage College Dictionary. (1993). (3rd ed.). Boston: Houghton Mifflin Company.

Adams, A. E. (2006). *Inferences and the role of prior knowledge.* Unpublished thesis. Georgia Institute of Technology Atlanta, GA.

Barsalou, L. W. (2003). Situated simulation in the human conceptual system. *Language and Cognitive Processes, 18*, 513-562.

Basso, D., & Belardinelli, M. O. (2006). The role of the feedforward paradigm in cognitive psychology. *Cognitive Processing, 7,* 73-88.

Bastick, T. (1982). *Intuition: How We Think and Act*. Chichester, England: John Wiley & Sons.

Baylor, A. L. (2001). A U-shaped model for the development of intuition by level of expertise. *New Ideas in Psychology, 19*, 237-244.

Beale, R. (2007). Slanty design. *Conmmunications of the ACM, 50*, 21-24.

Beck, M. R., Peterson, M. S., & Vomela, M. (2006). Memory for where, but not what, is used during visual search. *Journal of Experimental Psychology: Human Perception and Performance, 32*, 235-250.

Blackler, A., Popovic, V., & Mahar, D. (2003a). *Designing for intuitive use of products: An investigation.* Paper presented at the 6th Asian Design Conference, Tsukuba, Japan.

Blackler, A., Popovic, V., & Mahar, D. (2003b). The nature of intuitive use of products:An experimental approach. *Design Studies, 24*, 491-506.

Blackler, A. (2006). *Intuitive interaction with complex artefacts*. Unpublished dissertation. Queensland University of Technology, Brisbane, Australia.

Blackler, A., Popovic, V., & Mahar, D. (2006). *Toward a design methodology for applying intutive interaction*. Paper presented at the WonderGround: 2006 Design Research Society International Conference, Lisbon.

Blackler, A., & Hurtienne, J. (2007). Towards a unified view of intuitive interaction: Definitions, models and tools across the world. *MMI-Interaktiv, 13*, 37-55.

Blackwell, A. F. (2006). The reification of metaphor as a design tool. *ACM Transactions on Computer-Human Interaction, 13*, 490-530.

Blake, M. (1973). Prediction of recognition when recall fails: Exploring the feeling-of-knowing phenomenon. *Journal of Verbal Learning & Verbal Behavior, 12*, 311-319.

Bouthilet, L. (1948). *The measurement of intuitive thinking*. Unpublished Dissertation, University of Chicago, Chicago.

Bowers, K. S., Regehr, G., Balthazard, C., & Parker, K. (1990). Intuition in the context of discovery. *Cognitive Psychology, 22*, 72-110.

Brehmer, B., & Hogarth, R. M. (1990). Strategies in real-time, dynamic decision making. In R. M. Hogarth (Ed.), *Insights in decision making: A tribute to Hillel J. Einhorn*, pp. 262-279. Chicago: University of Chicago Press.

Brunswik, E. (1955). Representative design and probabilistic theory in a functional psychology. *Psychological Review, 62*, 193-217.

Byrne, M. D., Kirlik, A., & Fick, C.S. (2006). Kilograms matter: Rational analysis, ecological rationality, and closed-loop modeling of interactive cognition and behavior. In A. Kirlik (Ed.), *Adaptive Perspectives on Human-Technology Interaction: Methods and Models for Cognitive Engineering and Human-Computer Interaction,* pp. 267-284. New York: Oxford University Press.

Carroll, J. M., & Mack, Robert L. (1984). Learning to use a word processor: By doing, by thinking, and by knowing. In J. C. Thomas, & Schneider, M.L. (Ed.), *Human factors in computer systems,* pp. 13-51. Norwood, NJ: Ablex Publishing Corp.

Carroll, J. M., & Mazur, S.A. (1986). Learning Lisa. *IEEE Computer, 91*, 35-49.

Carroll, J. M. & Rosson, M.B. (1987). Paradox of the active user. In J. M. Carroll (Ed.), *Interfacing Thought: Cognitive Aspects of Human-Computer Interaction,* pp. 80-111. Cambridge, MA: MIT Press.

Chi, M. T. H. (2006). Laboratory methods for assessing experts' and novices' knowledge. In K. A. Ericsson, N. Charness, R. R. Hoffman & P. J. Feltovich (Eds.), *The Cambridge handbook of expertise and expert performance*, pp. 167-184. New York: Cambridge University Press.

Clark, A. (2000). Visual awareness and visuomotor action. In R. F. Nunez, W.J. (Ed.), *Reclaiming Cognition: The Primacy of action, intention and emotion Vol. 6*, pp. 1-18. Bowling Green, OH: Imprint Academic.

Connell, B. R., Jones, M., Mace, R., Mueller, J., Mullick, A., Ostroff, E., et al. (1997, 4/1/97). *The principles of universal design*. Retrieved 6/25/07, from www.design.ncsu.edu/cud/about_ud/udprinciplestext.htm

Cooper, A. (1995). *About Face: The Essentials of User Interface Design*. Foster City, CA: IDG Books Worldwide.

Daniels, U. P. (1973). *The effect of perceived locus of control and psychological stress on intuitive problem-solving*. Unpublished dissertation. York University, Toronto.

Davis-Floyd, R., & Arvidson, P.S. (Ed.). (1997). *Intuition: The Inside Story*. New York: Routledge.

Degani, A., Shafto, M., & Kirlik, A. (2006). What makes vicarious functioning work? Exploring the geometry of human-computer interaction. In A. Kirlik (Ed.), *Adaptive Perspectives on Human-Technology Interaction: Methods and Models for Cognitive Engineering and Human-Computer Interactions,* pp. 173-196. Oxford, England: Oxford University Press.

Djajadiningrat, T., Overbeeke, K., & Wensveen, S. (2002). *But how, Donald, tell us how? On the creation of meaning in interaction design through feedforward and inherent feedback.* Paper presented at the Designing Interactive Systems: Processes, Practices, Methods, and Techniques, London.

Djajadiningrat, T., Wensveen, S., Frens, J., & Overbeeke, C. (2004). Tangible products: redressing the balance between appearance and action, *Personal and Ubiquitous Computing, 8*, 294-309.

Earle, T. C. (1972). *Intuitive and analytical thinking in consistent and inconsistent multiple-cue learning tasks*. Unpublished dissertation, University of Oregon, Eugene, OR.

Ehret, B. D. (2002). *Learning where to look: Location learning in graphical user interfaces*. Paper presented at the SIGCHI conference on Human factors in computing systems: Changing our world, changing ourselves, Minneapolis, MN.

Farris, J. S. (2003). *The human-web interaction cycle: A proposed and tested framework of perception, cognition, and action on the web*. Unpublished dissertation, Kansas State, Manhattan, KS.

Flach, J. M. (1995). The ecology of human-machine systems: A personal history. In J. M. Flach, Hancock, P.A., Caird, J., & Vicente, K.J. (Ed.), *Global Perspectives on the Ecology of Human-Machine Systems*, pp. 1-13. Hillsdale, NJ: Lawrence Erlbaum Associates.

Freudenthal, A. (1999). *The Design of Home Appliances for Young and Old Consumers (Vol. 2)*. Delft, The Netherlands: Delft University Press.

Gibson, J. J. (1986). *The Ecological Approach to Visual Perception*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Gigerenzer, G., & Kurz, E.M. (2001). Vicarious functioning reconsidered: A fast and frugal lens model. In K. Hammond, & Steward T. (Ed.), *The Essential Brunswik: Beginnings, Expectations, Explications*, pp. 342-347. Oxford, England: University Press.

Goldstone, R. L. (1998). Perceptual learning. *Annual Review of Psychology, 49,* 585.

Gray, W. D. (2006). The emerging rapprochement between cognitive and ecological analyses. In A. Kirlik (Ed.), *Adaptive Perspectives on Human-Technology Interaction: Methods and Modles for Cognitive Engineering and Human-Computer Interaction*, pp. 230-246. Oxford, England: Oxford University Press.

Gray, W. D., & Boehm-Davis, D. A. (2000). Milliseconds matter: An introduction to microstrategies and to their use in describing and predicting interactive behavior. *Journal of Experimental Psychology: Applied, 6*, 322-335.

Gray, W. D., & Fu, W.-T. (2004). Soft constraints in interactive behavior: The case of ignoring perfect knowledge in-the-world for imperfect knowledge in-the-head. *Cognitive Science, 28,* 359-382.

Hamm, R. M. (1988). Moment-by-moment variation in experts' analytic and intuitive cognitive activity. *IEEE Transactions on Systems, Man and Cybernetics, 18*, 757-777.

Hammond, K. (1993). Naturalistic decision-making from a Brunswikian viewpoint: Its past, present and future. In G. Klein, Orasanu (Ed.), *Decision-making in Action: Models and Methods,* pp. 205-227. Westport, CT: Ablex Publishing.

Hammond, K. R. (1988). Judgment and decision-making in dynamic tasks. *Information and Decision Technologies, 14*, 3-14.

Henderson, M. C. (1999). *The effects of task properties and accountability on auditor performance: A test using the cognitive continuum theory.* Unpublished dissertation, University of Georgia, Athens, GA.

Hertzog, C., & Hultsch, D.F. (2000). Metacognition in adulthood and old age. In F. I. Craik, Salthouse, T.A. (Ed.), *Handbook of Aging and Cognition*, pp. 417-466. Mahwah, NJ: Lawrence Erlbaum Associates.

Hogarth, R. M. (2001). *Educating Intuition*. Chicago: University of Chicago Press.

Hogarth, R. M., Gibbs, B. J., McKenzie, C. R., & Marquis, M. A. (1991). Learning from feedback: Exactingness and incentives. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 734-752.

Hollnagel, E. (2002). Time and time again. *Theoretical Issues in Ergonomics Science, 3*, 143-158.

Hollnagel, E. (2005). *Extended Control Model (ECOM)*.   Retrieved 2/28/2007, from www.ida.liu.se/~eriho/ECOM_M.htm

Horrey, W. J., Wickens, C. D., Strauss, R., Kirlik, A., & Stewart, T. R. (2006). Supporting situation assessment through attention guidance and diagnostic aiding: The benefits and costs of display enhancement on judgment skill. In A. Kirlik (Ed.), *Adaptive perspectives on human-technology interaction: Methods and models for cognitive engineering and human-computer interaction,*. pp. 55-70, Oxford, England: Oxford University Press.

Howie, D. E., Vicente, K.J. (1998). Making the most of ecological interface design: The role of self-explanation. *International Journal of Human-Computer Studies, 49,* 651-674.

Hutchins, E. L., Hollan, J.D., and Norman, D.A. (1986). Direct manipulation interfaces. In D. A. Norman & S. W. Draper (Ed.), *User Centered System Design*, pp. 87-124. Hillsdale, NJ: Erlbaum.

Jagacinski, R. J., & Flach, J.M. (2003). *Control theory for humans: Quantitative approaches to modeling performance*. Mahwah, NJ: Lawrence Erlbaum Associates.

Jones, K. S., Farris, J. S., & Johnson, B. R. (2005). Why does the negative impact of inconsistent knowledge on web navigation persist? *International Journal of Human-Computer Interaction*, *19*, 201-221.

Kahneman, D., & Frederick, S. (2002). Representativeness revisited: Attributed substitution in intuitive judgment. In T. Gilovich, Griffin, D., & Kahneman, D. (Ed.), *Heuristics and Biases: The psychology of intuitive judgment*, pp. 49-81. Cambridge, UK: Cambridge University Press.

Kahneman, D. (2003). A perspective on judgment and choice: Mapping bounded rationality. *American Psychologist*, *58*, 697-720.

Kahneman, D., & Frederick, S. (2005). A model of heuristic judgment. In K. J. Holyoak & R. G. Morrison (Eds.), *The Cambridge handbook of thinking and reasoning.* (pp. 267-293). New York: Cambridge University Press.

Kirlik, A. (1995). Requirements for psychological models to support design: Toward ecological task analysis. In J. M. Flach, P. A. Hancock, J. Caird & K. J. Vicente (Eds.), *Global perspectives on the ecology of human-machine systems, Vol. 1*, pp. 68-120. Hillsdale, NJ, England: Lawrence Erlbaum Associates, Inc.

Kirlik, A. (1998). *The ecological expert: Acting to create information to guide action*. Paper presented at the Conference on Human Interaction with Complex Systems (HICS '98), Piscataway, NJ.

Kirlik, A. (2001). On Gibson's review of Brunswik. In K. Hammond, & Steward T. (Ed.), *The Essential Brunswik: Beginnings, Expectations, Explications,* pp. 238-242. Oxford, England: Oxford University Press.

Kirlik, A. (2006). Abstracting situated action: Implications for cognitive modeling and interface design. In *Adaptive perspectives on human-technology interaction: Methods and models for cognitive engineering and human-computer interaction*, pp. 212-224: Oxford, England: Oxford University Press.

Klein, G. (1997). The recognition-primed decision (RPD) model: Looking back, looking forward. In

C. E. Zsambok, Klein, G. (Ed.), *Naturalistic Decision-Making*, pp. 285-292. Mahwah, NJ: Lawrence Erlbaum Publishers.

Klein, G. A. (1993). A recognition-primed decision (RPD) model of rapid decision making. In G. A. Klein, Orasanu, J., Calderwood, R, Zsambok, C.E. (Ed.), *Decision making in action: Models and methods*, pp. 138-147. Westport, CT: Ablex Publishing.

Koriat, A., Ben-Zur, H., & Nussbaum, A. (1990). Encoding information for future action: Memory for to-be-performed tasks versus memory for to-be-recalled tasks. *Memory & Cognition, 18*, 568-578.

Kurniawan, S. H. (2001). *Using GOMS to predict older adults' search time of health information in a hierarchical structure*. Unpublished dissertation. Wayne State University, Detroit, MI.

Larkin, J., McDermott, J., Simon, D. P., & Simon, H. A. (1980). Expert and novice performance in solving physics problems. *Science, 208*, 1335-1342.

Lewis, C. & Mack, R. (1982). *Learning to use a text processing system: Evidence from "thinking aloud" protocols*. Paper presented at the Conference on Human Factors in Computing Systems, Gaithersburg, MD.

Lieberman, M. D. (2000). Intuition: A social cognitive neuroscience approach. *Psychological Bulletin, 126*, 109-137.

Lipshitz, R. (1993). Decision making as argument-driven action. In G. A. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision making in action: Models and methods*, pp. 172-181. Norwood, NJ: Ablex Publishing.

Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review, 109*, 376-400.

Marr, M. J. (2003). The stitching and the unstitching: What can behavior analysis have to say about creativity? *Behavior Analyst, 26*, 15-27.

Mather, M., Canli, T., English, T., Whitfield, S., Wais, P., Ochsner, K., et al. . (2004). Amygdala responses to emotionally valenced stimuli in older and younger adults. *Psychological Science, 15*, 259-263.

Mayfield, R. (2005). *Doug Engelbart, Rebooted*. Retrieved 10/26/2007, from http://ross.typepad.com/blog/2005/06/index.html

Mayhew, D. J. (1999). *The Usability Engineering Lifecycle: A Practitioner's Handbook for User Interface Design*. San Francisco, CA: Morgan Kaufmann Publishers Inc.

McMackin, J., & Slovic, P. (2000). When does explicit justification impair decision making? *Applied Cognitive Psychology, 14*, 527-541.

Miller, C. C., & Ireland, R. D. (2005). Intuition in strategic decision making: Friend or foe in the fast-paced 21st century? *Academy of Management Executive, 19*, 19-30.

Mitchell, C. T. (1996). *New Thinking in Design: Conversations on Theory and Practice*. New York: Van Nostrand Reinhold.

Mullet, K. & Sano, D. (1995). *Designing Visual Interfaces: Communication Oriented Techniques*. Englewood Cliffs, NJ: Prentice Hall PTR.

Nielsen, J. (1994). *Usability Engineering*. Boston: AP Professional.

Norman, D. A. (1990). The problem of automation: Inappropriate feedback and interaction, not 'over-automation'. In D. E. Broadbent, J.T. Reason, & A.D. Baddeley, (Ed.), *Human Factors in Hazardous Situations*, pp. 137-145. New York: Clarendon Press.

Norman, D.A. (1999). Affordances, conventions, and design. *Interactions, 6*, 38-43.

Norman, D. A. (2002). *The design of everyday things*. New York: Basic Books.

Norman, D. A. (2005). *Emotional Design: Why We Love (or Hate) Everyday Things*. New York: Basic Books.

Norman, D. A., & Shallice, T. (1986). *Attention to action: Willed and automatic control of behavior* San Diego, CA: Center for Human Information Processing.

O'Brien, M. A., Rogers, W.A., & Fisk, A.D. (in press). Evaluating design features that affect older adults' performance on common computer tasks. In A. Mihailidis (Ed.), Technology and Aging. Amsterdam: IOS Press.

Overbeeke, C. J., & Wensveen, S.A.G. (2003). *From perception to experience: From affordances to irresistibles*. Paper presented at the Proceedings of the 2003 international conference on Designing pleasurable products and interfaces, Pittsburgh, PA.

Payne, S. J., Richardson, J., & Howes, A. (2000). Strategic use of familiarity in display-based problem solving. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 1685-1701.

Pennington, N., & Hastie, R. (1993). A theory of explanation-based decision-making. In G. A. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision-making in Action: Models and methods*, pp. 188-201. Norwood, NJ: Ablex Publishing.

Pirolli, P. (2006). The use of proximal information scent to forage for distal content on the world wide web. In A. Kirlik (Ed.), *Adaptive Perspectives on Human-Technology Interaction: Methods and Modles for Cognitive Engineering and Human-Computer Interaction*, pp. 247-266. Oxford, England: Oxford University Press.

Pirolli, P., & Card, S. (1999). Information foraging. *Psychological Review, 106*, 643-675.

Polson, P. G., & Lewis, C. H. (1990). Theory-based design for easily learned interfaces. *Human-Computer Interaction, 5*, 191-220.

Raskin, J. (1994). Viewpoint: Intuitive equals familiar. *Communications of the ACM, 37*, 17-18.

Rasmussen, J. (1993). Deciding and doing: Decision-making in natural context. In G. A. Klein, J. Orasanu, R. Calderwood & C. E. Zsambok (Eds.), *Decision-making in Action: Models and Methods*, pp. 158-171. Norwood, NJ: Ablex Publishing.

Rayner, K. (1981). Masking of foveal and parafoveal vision during eye fixations in reading. *Journal of Experimental Psychology: Human Perception and Performance, 7*, 167-179.

Rieman, J., Young, R. M., & Howes, A. (1996). A dual-space model of iteratively deepening exploratory learning. *International Journal of Human-Computer Studies, 44*, 743-775.

Salvendy, G. (Ed.). (1997). *Handbook of Human Factors and Ergonomics (2nd ed.)*. New York: John Wiley & Sons, Inc.

Schmidt, R. A. (1987). The acquisition of skill: Some modifications to the perception-action relationship through practice. In H. Heuer, & A.F. Sanders (Ed.), *Perspective on Perception and Action*, pp. 77-103. Hillsdale, NJ: Lawrence Erlbaum Associates.

Schneider, W., Dumais, S.T., & Shiffrin, R.M. (1984). Automatic and control processing and attention. In Parasuraman (Ed.), *Varieties of Attention*, pp. 1-27. Orlando, FL: Academic Press.

Schneider, W., & Fisk, A.D. (1984). Automatic category search and its transfer. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10*, 1-15.

Schneiderman, B. (1998). *Designing the User Interface: Strategies for Effective Human-Computer Interaction (3rd ed.)*. Reading, MA: Addison-Wesley.

Simmons, J.P., & Nelson, L.D. (2006). Intuitive confidence: Choosing between intuitive and nonintuitive alternatives. *Journal of Experimental Psychology: General, 135*, 409-428.

Simonton, D. K. (1980). Intuition and analysis: A predictive and explanatory model. *Genetic Psychology Monographs, 102*, 3-60.

Sinclair, M., & Ashkanasy, N. M. (2005). Intuition: Myth or a decision-making tool? *Management Learning, 36*, 353-370.

Singley, M. K., & Anderson, J. R. (1987). A keystroke analysis of learning and transfer in text editing. *Human-Computer Interaction*, *3*, 223.

Skinner, B. F. (1969). *Contingencies of Reinforcement*. New York: Meredith Corporation.

Sloman, S. A. (1996). The empirical case for two systems of reasoning. *Psychological Bulletin, 119*, 3-22.

Spool, J. (2005). *What makes a design seem "intuitive"?* [Electronic Version]. Retrieved 7/17/07 from http://uie.com/articles/design_intuitive/.

Tidwell, J. (2005). *Designing interfaces*. Sebastopol, CA: O'Reilly Media.

Todd, P. M., & Gigerenzer, G. (2007). Environments that make us smart: Ecological rationality. *Current Directions in Psychological Science*, *16*, 167-171.

Tsodyks, M., & Gilbert, C. (2004). Neural networks and perceptual learning. *Nature, 431*, 775-781.

Tversky, A., & Kahneman, D. (1971). Belief inj the law of small numbers. *Psychological Bulletin, 76,* 105-110.

Volz, K. G., & Von Cramon, D. Y. (2006). What neuroscience can tell about intuitive processes in the context of perceptual discovery. *Journal of Cognitive Neuroscience, 18*, 2077-2087.

Westcott, M. R. (1961). On the measurement of intuitive leaps. *Psychological Reports, 9*, 267-274.

Westcott, M. R. (1968). *Toward a contemporary psychology of intuition: A historical, theoretical, and empirical inquiry*. New York: Rinehard & Winston.

Wickens, C. D., Gordon, S.E., & Liu, Y. (1998). *An Introduction to Human Factors Engineering*. New York: Addison Wesley Longman, Inc.

Wickens, C. D., & Hollands, J.G. (2000). *Engineering Psychology and Human Performance (3rd ed.)*. Upper Saddle River, NJ: Prentice Hall.

Yang, G.-Z., Dempere-Marco, L., Hu, X.-P., Rowe, A. (2002). Visual search: Psychophysical models and practical applications. *Image & Vision Computing, 20*, 291-305

APPENDIX A – DEFINITIONS OF INTUITIVE

Reference	Research Domain	Definition
Allen & Buie, (2002) p. 18	human-computer interaction	intuitive interface means that it "asks no more of user than what he either already knows or can immedately deduce from previous life experience"; may be shared with community of users familiar with the task and environment
Bastick, (1982) p. 8	psychology	defined in terms of properties and formalize previously vague terms
Bastick, (1982) p. 354	psychology	"the fundamental process of thought and behavior that results from organization of information in our brain that emotionally encoded"
Baylor, (2001) p. 187	psychology, measurement	results from a reasoning process that lacks metacognitive control
Baylor, (2001) p. 191	psychology, measurement	intuion is "moment of transition from first stage (I know what I'm looking for) to second stage (I know what to do); gearing knowledge into action, with justifying elements implicity"
Blackler, Popovic, & Mahar (2003b) p. 491	psychology	"type of cognitive processing that is often unconscious and utilizes stored knowledge"
Blackler, Popovic, & Mahar (2003b) p. 492	psychology	intuition operationalized as "relevant past experience"
Blackler & Hurtienne (2007), p. 38	human-computer interaction	"Intuitive use of products involves utilising knowledge gained through other experience(s). Therefore, products that people use intuitively are those with features they have encountered before. Intuitive interaction is fast and generally non-conscious, so people may be unable to explain how they made decisions during intuitive interaction"
Bouthilet (1948), p. 49	psychology	"discrimination without awareness, correct reactions to stimuli purportedly not sensed, more than chance proportions of judgements made on basis of guesses, gradual, hunchlinke emergence of recognition of classifcatory schemes & relationships"
Bouthilet (1948), p. 57	psychology, measurement	"capacity to make correct guesses without knowing why"
Bowers, Regehr, Balthazard, & Parker (1990), p. 72	psychology, measurement	"informed judgment in the context of discovery"
Bowers, Regehr, Balthazard, & Parker (1990), p. 73	psychology, measurement	distinct information processing mode, unconsciously stored information is used to guide decisions & problem-solving; "model of intuition implies role of memory and experience in judgment and problem solving"

Reference	Research Domain	Definition
Bowers, Regehr, Balthazard, & Parker (1990), p. 74	psychology, measurement	"preliminary perception of coherence (pattern, meaing, structure) that is at first, not consciously represented, but which nevertheless guides thought and inquiry toward a hunch or hypothesis about the nature of the coherence in question)
Bruner (1949), cited in Hammond (1996), p. 85	management decision-making	"the intellectual technique of arriving at plausible but tentative formulations without going through the analytic steps by which such formulations would be found to be valid or invalid conclusions"
Cooper 1995, p. 56	human-computer interaction	"works from inference where one sees the connections between objects and learns from similarities but are not distracted by differences" "has a magical quality"
Earle (1972), p. 12	decision-making	"thinking in the intuitive mode is fast, uses a variety of information, has a low degree of awareness, and is seldom precisely correct or drastically wrong"
Eggen, Haakma, & Westerink (1996)	human-computer interaction	implied meaning is speculation
Ehrlich (1996)	human-computer interaction	implied meaning is obvious, self-evident, self-explanatory
Einhorn & Hogarth (1987), p. 70	management decision-making	Implied meaning is "hypothesis of cause"
Evans, Clibbens, Cattani, Harris, & Dennis (2003), p. 608	management decision-making	intuitive implies that people who lack self-insight into the processes underlying judgments may be unconsciously biased;
Freudenthal & Mook, 2003	human-computer interaction	implied that intuitive means used with no instructions, quite easily
Hammond, Hamm, Grassia, & Pearson (1987), p. 755,	decision-making	intuition has "low cognitive control", "rapid data processing", "low conscious awareness", weighted average organizing principle", "normally distributed errors", high confidence in answer, low confidence in method"
Hammond, Hamm, Grassia, & Pearson (1987), p. 758	decision-making	no known algorithm exists for organizing the cues used to judgment the information & how cues should be used
Hammond, Hamm, Grassia, & Pearson, (1987)	decision-making	Intuition constructs estimates based on underlying statistical nature
Hammond (1996), p. 60	decision-making	"cognitive process that somehow produces an answer, solution, or idea without the use of a conscious, logically defensible, step-by-step process"
Hammond, (1996), p. 191:	decision-making	"custom, tradition, irrational allegiance"
Harbort (1997) p. 135	decision-making	"operationally, in this context, intuition is the process of imagining something that turns out to be true', where true is "person is willing to do something about it"

Reference	Research Domain	Definition
Harbort (1997), p. 136	decision-making	"intuition as a psychological construct allows an individual to use creative faculties to deal with real-world problems"
Hogarth (2001) p. 249	decision-making	"The essence of intution or intutive responses is that they are reached with little apparent effort and typically without conscious awareness. They involve little or no conscious deliberation"
Hogarth (2001) p. 7 (surmised)	decision-making	characterized by "elements of speed in knowing", "lack of deliberative or rational thought process", "using a store of knowledge […] built up over time through past intuitions" with link to "insight"
Hogarth (2001) p. 7 (surmised)	decision-making	also implied "lack of awareness of *how* outcomes are achieved", with heavy influences by Brunswik's model of perception
Kahneman, 2003	decision-making	thoughts and preferences that come to mind quickly & without much reflection
Kahneman, 2003, p. 703	decision-making	"intuitive decisions are shaped by the factors that determine the accessible features of the situation. Highly accessible features influence decisions, whereas features of low accessibility are largely ignored." "Intuitive judgments are not modified by analytical systems"
Kahneman, 2003	decision-making	answer to an easy question when a difficult one is required
Kirlik, 1995	cognitive engineering	implied that intuitive is the same as fluent interaction
Langan-Fox & Shirley (2003) p. 208	management decision-making	general definition cited from Vaugh, 1979, p. 46) is "knowing without being able to explain how we know"
Larkin, McDermott, Simon, & Simon (1980)	psychology	physical intuition (for physicists solving phyisical problems): solving difficult problems rapidly and without much conscious deliberation about a plan of attack, chess intution: rapid & accurate possession of information
Li, (personal communication), 6/18/2007	human-computer interaction	intuitive operations means that "the way of operation is visible without extra thought", "you can follow your own way of doing things", "you know at a glance what to do", "transparent interactin" "way it looks conforms to your mental model"… "initial usability" vs. long-term characteristics
Lieberman (2000), p. 109	neuroscience	"the subjective experience associated withuse of knowledge gained through implict learning"
Lieberman (2000), p. 111	neuroscience	"subjective experience of a mostly nonconscious process that is fast, alogical, and inaccessible to consciousness that dependent on exposure to ethe domain or problem space, is capable of accurately extracting probabilistic contingencies"
Mack & Montaniz (1994), p. 299	human-computer interaction	Parenthetical meaning of "intuitively" is "without specialized [inspection] guidelines"

Reference	Research Domain	Definition
Mohs, Hurtienne, Israel, Nauman, Kindsmuller, Meyer, & Pohlmeyer (2006) cited in Blackler & Hurtienne (2007) p. 44	human-computer interaction	"A technical system is intuitively usable if the users‘ unconscious application of prior knowledge leads to effective interaction."
Miller & Ireland (2005), p. 20	management decision-making	"at the core of intuition is a set of insights and understandings that is not known fully to its owner"
Miller & Ireland (2005), p. 20	management decision-making	"thoughts, conclusions or choices produced largely or in part through subconscious mental processes… a holistic hunch and as automated expertise"
Miller & Ireland (2005), p. 20	management decision-making	holistic hunch: judgement or choice made through a subconscious synthesis of information drawn from diverse experiences"; often with novel approaches & actions counter to prevailing thinking or data. "gut feeling"
Miller & Ireland (2005), p. 20	management decision-making	automated expertise: "recognition of a famliar situation and the straightforward but partially subconscious application of previous learning related to that situation"
Myers, McCaulley, Quenk, & Hammer (1990), p. 24	psychology	"the perception of possibilities, meanings, and relations" citing Jung, perception by way of the unconscious". "may come ot the surface of consciousness as hunch or suddent discovery of a pattern of seemingly unrelated events"
Olsson, Enkvist, & Juslin (2006), p. 1371	decision-making	intutive implied by implicit, silent knowledge based on personal experience
Pirolli & Card (1999)	human-computer interaction	implied meaning is quick, educated guess about what may happen
Raskin (1994), p. 17	human-computer interaction	"intuitive" as a form of praise for an interface "give the impression that the interface works the way the user does, that normal human "intuition" suffices to use it, that neither training nor rational thought is necessary, and that it will be natural"
Raskin (1994), p. 18	human-computer interaction	uses readily transferred existing skills
Raskin (1994), p. 18	human-computer interaction	Familiar
Shirley & Langan-Fox (1996), p. 564	management decision-making	"a feeling of knowing with certitude on the basisi of inadequte information and without conscious awarness of rational"
Simmons & Nelson (2006)	management decision-making	answer to an easy question when a difficult one is required (derived from Kahneman & Fredericks, 2002)
Simmons & Nelson (2006), p. 409	management decision-making	"the first answer that springs to mind when one is required to make a decision"

Reference	Research Domain	Definition
Sinclair & Ashkanasy (2005), p. 353	management decision-making	"non-sequential information processing mode, which comprises both cognitive and affective elements & results in knowing without any use of conscious reasoning"
Skinner (1974) (cited in Marr 2003, p. XX)	psychology	" behaving intuitively in the sense of behaving as the effect of unanalyzed contingencies is the very starting point of a behavior analysis
Skinner, 1974 (cited in Marr 2003, p. 24)	psychology	expression of contingency shaped behavior (vs. rule-governed behavior)
Skinner, 1974 (cited in Marr 2003, p. 24)	psychology	behaving intuitively as behaving as the effect of unanalyzed contingencies is the very starting
Spool (2005)	human-computer interaction	based on experience, though he often means that users can figure out the system without training (but not clear from definition if it's problem-solving or intuition - like direct perception)
Volz & von Cramon (2006), p. 2077	neuroscience	operationalized as "preliminary perception of coherence in the context of (visual) discovery"
Volz & von Cramon (2006), p. 2077	neuroscience	"preliminary perception of coherence (pattern, meaing, structure) that is at first, not consciously represented, but instead embodied in a gut feeling or an initial guess that subsequently biases or thought and inquiry"
Westcott (1961), p. 268	psychology	"individuals reach valid conclusions by iinexplcit means, based on what others consider insufficient information"
Westcott (1968), p. 97	psychology	"occurs when an individual reaches a conclusion on the basis of less explicit information than is ordinarily required to reach that conclusion"

APPENDIX B – KEY ATTRIBUTES RELEVANT TO INTUITIVE DESIGN

	Key Descriptor for attribute	Synonyms and elaborations of attribute from literature review						
1	Perception of quick, immediate, sudden appearance	speed of cognitive activity	immediate & concrete awareness of cues & goal	perceptual measurement of cues	holistic			
2	precursors/ antecedents to intuition	gradual improvement						
3	subjective certainty of correctness	feeling of importance	familiarity					
4	emotional involvement	understanding by feeling - emotive not tactile	empathy - kinesthetic knowledge	harmonious	(low) anxiety			
5	seeking coherence	harmony/ beauty	pattern-seeking vs. functional relational thinking	motivation	goal state	sense of relations	simplicity	
6	recentering	finding constraints (reasons for rejecting)	associative	use of stories to explain/ understand	associations with egocentricity	mental simulation	problem-solving	
		discovery	associations with creativity	unlimited, novel combinations	low barriers between ideas	hypnogogic reverie	transfer and transposition	
7	need not be correct	cognitive control (reliability/consistency)	variety of process execution (even by one individual)	lack of organizing principle for answer	distribution of errors	accuracy not needed	(low) confidence in method	risk-taking
8	preconscious process (can only demonstrate knowledge)	automatic	hard to suppress or inhibit	non-transparency	verbal may interfere with			
		preverbal knowledge	preverbal process (low awareness of cogntive activity)	difficult to control or modify	self-evident (explains itself)	innate, instinctive knowledge		
9	influenced by prior experience	implicit knowledge and learning	global knowledge	domain knowledge	metaphors used	use of mental models		
10	expectancies	working forward	operant conditioning	open-loop strategy	feedforward	feedback	action-focused	task predictability
11	incomplete knowledge	Pattern matching	uncertainty about probabilities & consequences of options	relationship of cues to criterion	categorization	use of heuristics		
		feature-matching	frugal (search for only a few [discriminating] cues)	recognition (vs. recall)	cue intersubstitutability	cue usage	noise	
12	type of cue	correlational (not causal)	cue accessibility	level of cue overlap	cue redundancy	visual stimuli		
		number of cues	surface vs. depth task characteristics	differential weighting of cues	continuous values of stimuli	relevant cues	causal properties	
		use of automation vs. not	cues displayed simultaneously	concreteness of cues	structure of stimuli	stimulus complexity	clarity of perceptual cues	
13	subjective ease of judgment development	limited resources	low cognitive load	interaction of context & subjective ease of judgment	Limited time	low effort		
14	dependence on environment	context-specific	Other task complexity	contextual variables (constraints)				
15	attentional focus	scan control	access to peripheral cues					

16	individual differences	field independence	
17	contrast with abstract reasoning, logic, or analytic thought	complementarity of analytic with intuitive	one side of cognitive continuum

Legend for coloration of attributes (colors shown below represent the first reference for each descriptor, synonym or elaboration as shown in Appendix B).

Bouthilet, 1948	Larkin, 1980	Hammond, Hamm, Grassia, & Pearson, 1987	Rasmussen, 1993	Shirley & Langan-Fox, 1996	Simmons & Nelson, 2006
Westcott, 1961	Simonton, 1980	Hammond, 1988	Kirlik, 1995	Harbort, 1997	
Westcott, 1968	Bastick, 1982	Brehmer & Hogarth, 1990	Hammond, 1996	Sinclair 2005	
Earle, 1972	Einhorn & Hogarth, 1987	Hammond, 1993	Kirlik, Walker et al 1996	Horrey et al 2006	

APPENDIX C –LIST OF ATTRIBUTES EXTRACTED FROM LITERATURE REVIEW

Key attribute	*Elaborations from other research*
Quick, immediate, sudden appearance	Speed of cognitive activity Immediate and concrete awareness of cues and goal Perceptual measurement of cues Holistic
Precursors/ antecedents to intuition	Gradual improvement
Subjective certainty of correctness	Feeling of importance Familiarity
Emotional involvement	Understanding by feeling – emotive, not tactile Empathy, kinesthetic knowledge Harmonious (Low) anxiety
Seeking coherence	Harmony/ beauty Simplicity Motivation Goal state Sense of relations Pattern-seeking vs. functional relational thinking
Recentering	Finding constraints (reasons for rejecting) Associative Use of stories to explain/ understand Mental simulation Problem-solving Discovery Associations with creativity Unlimited, novel combinations Low barriers between ideas Hypnogogic reverie (dream state) Transfer and transposition Associations with egocentricity
Need not be correct	Cognitive control (reliability/ consistency) Variety of process execution (even by one individual) Risk-taking Distribution of errors Accuracy not needed Lack of organizing principle for answer Low confidence in method

Key attribute	*Elaborations from other research*
Preconscious process (can only demonstrate knowledge)	Automatic Hard to suppress or inhibit Non-transparency Verbal may interfere with Preverbal knowledge Preverbal process (low awareness of cognitive activity) Difficult to control or modify Self-evident (explains itself) Innate, instinctive knowledge
Influenced by prior experience/ knowledge	Implicit knowledge and learning Global knowledge Domain knowledge Metaphors used Use of mental models
Expectancies	Working forward Operant conditioning Open-loop strategy Feedforward Feedback Action-focused Task predictability
Incomplete knowledge	Pattern matching Feature matching Relationships of cues to criterion Categorization Use of heuristics Recognition vs. recall Frugal search for only a few (discriminating) cues Uncertainty about probabilities and consequences of options Cue intersubstitutability Cue usage Noise

Key attribute	*Elaborations from other research*
Type of cue	Correlational (not causal) Cue accessibility Level of cue overlap Cue redundancy Visual stimuli Number of cues Surface vs. depth task characteristics Differential weighting of cues Continuous values of stimuli Relevant cues Causal properties Use of automation or not Cues displayed simultaneously Concreteness of cues Structure of stimuli Stimulus complexity Clarity of perceptual cues
Subjective ease of judgment development	Limited resources Low cognitive load Interaction of context and subjective ease of judgment Limited time Low effort
Dependence on environment	Context-specific Other task complexity Contextual variables (constraints)
Attentional focus	Access to peripheral cues Scan control
Individual differences	Field independence
Contrast with abstract reasoning, logic, or abstract thought	Complementarity of analytic with intuitive One side of cognitive continuum

APPENDIX D – MAPPING OF INDIVIDUAL GUIDELINES (ROWS)

WITH GUIDELINE SOURCES (COLUMNS)

	Apple Human Interface Guidelines 1987	Principles of Universal Design (Connell 1997)	Mayhew 1992	Nielsen 1994	Norman, 2002	Schneiderman 1998
Visibility of system status	✓		✓	✓	✓	
Match between system and real world (language, conventions & temporal order)		✓		✓		
User control and freedom (including undo and redo)	✓	✓		✓		✓
Consistency and standards (predictable, orderly, describable by few rules)	✓	✓	✓	✓	✓	✓
Error prevention		✓		✓	✓	✓
Recognition rather than recall	✓			✓	✓	✓
Flexibility and efficiency of use		✓		✓		✓
Aesthetic and minimalist	✓	✓	✓	✓		

	Apple Human Interface Guidelines 1987	Principles of Universal Design (Connell 1997)	Mayhew 1992	Nielsen 1994	Norman, 2002	Schneiderman 1998
design (only relevant information)						
Help users recognize, Diagnose and recover from errors	✓	✓		✓		✓
Help and documentation should be easy to search, focused on user's task, list recovery steps and not be too large				✓		
Provide informative feedback	✓	✓	✓		✓	✓
Design dialogs to yield closure		✓				✓
Present functionality through familiar metaphor	✓		✓		✓	✓
Use best practices for text display and usage, number display and	✓		✓			

	Apple Human Interface Guidelines 1987	Principles of Universal Design (Connell 1997)	Mayhew 1992	Nielsen 1994	Norman, 2002	Schneiderman 1998
usage, color display and usage, and coding techniques						
Get mappings right, use natural mappings		✓			✓	
Use WYSIWYG	✓					✓
Simplify structure of task	✓	✓			✓	
Exploit power of constraints		✓			✓	
Perceived stability (finite actions and objects)	✓	✓			✓	
Feedforward	✓	✓				
Clarity	✓	✓				
Equitable access		✓				
Intuitive use		✓				
Perceptible information		✓				
Low physical effort		✓				
Size & space for approach & use		✓				

APPENDIX E – MAPPING OF INTUITIVE FEATURES WITH GUIDELINES FROM APPENDIX D

	GUI User Interface Guidelines
Perception of quick, sudden appearance	Get mappings right/use natural mappings (affordances) Use WYSIWYG
Precursors to knowledge	
Subjective certainty of correctness	
Emotional involvement	
Seeking coherence	Equitable access Design dialogues to yield closure
Recentering	Exploit power of constraints Perceived stability (finite objects and actions available) Help users recognize, diagnose & recover from errors
Need not be correct	Help and documentation should be easy to search, focused on user's task, List recovery steps User control & freedom (including undo and redo)
Preconscious process	Get mappings right, use natural mappings
Influenced by experience	Present functionality through familiar metaphor Intuitive use Get mappings right, use natural mappings Match between system and real world (language, conventions & temporal order) Match between system and real world (language, conventions & temporal order)
Expectancies	Visibility of system status Flexibility and efficiency of use Help users recognize, diagnose & recover from errors Provide informative feedback Design dialogs to yield closure Feedforward Intuitive use Use WYSIWYG Simplify structure of task (subgoals?)
Incomplete knowledge	Recognition rather than recall Simplify structure of task Perceptible information
Type of cue	Perceptible information Aesthetic and minimalist design (only relevant information) Use best practices for text display and usage, number display and usage, color display and usage, and coding techniques Clarity

	GUI User Interface Guidelines
Subjective ease of effort	Low physical effort
Dependence on environment	Size & space for approach & use (think orientation & guiding how intuition is formed) Intuitive use (concentration level) Perceptible information
Attentional focus	Perceptible information
Individual differences	Equitable access Intuitive use Size & space for approach & use
Contrast with abstract reasoning or analytic thought	Error prevention

AUTHOR NOTE

This research was supported in part by contributions from Deere & Company. We thank Jerry Duncan and Josh Hoffman for their support and advice on this research. For more information about this project, please contact Wendy A. Rogers at wendy@gatech.edu.