

An Integrative Approach to User Interface Design

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INTRODUCTION

As we are witnessing an increase in multifunctionality of interactive devices, two problems are taking shape in user interface (UI) design: first, the problem of complexity, and second, the problem of fragmentation (Kljajevic, in press). The former is reflected in the fact that multipurpose interactive devices usually have interfaces that do not allow easy access to new functions and features, rendering the increased functionality useless. The second problem is related to the fragmentation in the current research paradigms and testing trends that inform UI design. These paradigms and trends stem mostly from psychological theories that focus on only some specific aspects of user-interface interaction. While it is important to investigate such topics in detail, it is even more important to look at the totality of the interaction and determine the principles that operate in it. An integrative approach to UI design has the potential to solve both problems. Such an approach has two components: a top-down and a bottom-up component. Its top-down component deals with a small set of basic cognitive principles that operate in interactive reality and therefore need to be recognized at the level of UI design. The principles are built into a cognitive architecture—a wide theoretical framework that corresponds to the human cognitive system—whose constraints prevent proliferation of implausible theories, which solves the fragmentation problem.

Since the principles within a top-down approach to UI design are too general and hard to quantify (Zacks & Tversky, 2003), its bottom-up component enables accurate specifications of each case of UI design. This is done via computational cognitive models. The models are used for rapid prototyping and evaluation, as well as for other requirements of iterative user-centered design. Thus, the integrative approach to UI design is a model-based design approach that unifies the domains of cognition, theory, methodology, and design in a principled way. The integrative approach emphasizes

the principles that operate in all four domains with the domains functioning as different levels of representation and interpretation of interactive reality.

The integration of the levels is driven by the economy principle, the principle of information structuring, and the relevance principle. The proposed cognitive principles are derived from many domains of cognitive research. Each of the principles operates at each of the levels. Thus, the basic principles of cognition are extended to theorizing about interactive reality to the construction of methodological tools for its theories (e.g., modeling) and design of specific products' interfaces.

It might seem that UI designers should deal with the principles at the level of design only. Although the level of design is necessary, taken in isolation, it is insufficient for a well-designed interface. This is because (a) cognition is the crucial element of human-computer interaction; that is, designers need to understand the cognitive processes involved in it (Peschl & Stary, 1998); (b) without a theory of cognition, any model of dynamic, interactive behavior, be it verbal or computational, is random, theoretically unconstrained, and as such scientifically not valid; and (c) iterative design could only benefit from the models that fully employ insights from cognitive science.

THE INTERACTIVE REALITY

I will use the term *interactive reality* to refer to the context of interactive behavior emerging from a user-task-artifact triad. A specific case of interactive behavior depends on (1) the elements of the triad, (2) complexity of the structural relations among the elements, and (3) the environment in which a task takes place. Thus, the term *interactive reality* implies that no matter how complex the dynamic interplay of user's cognition, perception, and motor actions is, it is the totality of the relations that emerge from the triad in each particular

case and the triad's interaction with the environment that determines the quality of the user's experience.

Given the complexity of interactive reality and that of the human cognitive system, it is confusing that UI design often assumes that the *rationality principle* is the only relevant principle that affects this reality. Indeed, cognitive scientists have long realized that "rationality does not determine behavior" (Simon, 1947, p. 241) and that the rational decision theory put forth by neoclassical economics is too idealized to be applied to everyday human life (Boden, 2006; Gardner, 1985).

As an example of irrational interactive behavior, consider "the paradox of the active user." The paradox consists in the user's preference of inefficient general procedures to the recommended specialized ones. Thus, the user's decisions on the steps in accomplishing a task are neither optimal nor rational choices. What is puzzling here is the users' persistence in employing the inefficient strategies even though in the long run these require more effort (Fu & Gray, 2004). More importantly, such behavior is guided by an inadequately designed UI. If the principle of rationality does not figure prominently in interactive behavior, then what are the principles that determine it? Here I outline three principles that appear to influence interactive behavior more than the principle of rationality.

DESIGN AS APPLIED SCIENCE

In a way, UI design seems to close the gap between "theory and practice," which has been open for millennia (Ohlsson, 2007). The distinction neatly emphasizes the divide between the two types of knowledge: theoretical type, or "knowledge that," and the practical type, or "knowledge how." UI design has the potential to become a mechanism for interfacing thought and action, bridging the big divide between theory and practice.

Card, Moran, and Newell (1983) have pointed out that knowledge of human behavior does not translate easily into guidelines on how to design interactive computer systems. In order to enable an easy transfer of knowledge from *theoretical psychology* to the *practice of design*, they proposed building "an *applied psychology* that includes theory, data, and knowledge" (p. vii). Within this applied approach, the key concept is *cognitive architecture* (CA), that is, a construct that attempts to explain the overall structure of the human cognition. CAs integrate the broadest range of human cognitive

phenomena (attention, vision, working memory, decision making, problem solving, learning), which makes them (and cognitive science in general) perfectly aligned with a major desideratum of science—unification of "seemingly disparate events."

A cognitive architecture is a theoretical framework which hypothesizes about those aspects of the human mind that are relatively constant over time and across tasks (Sun, 2004). More specifically, a particular CA is characterized by specific constraints that prevent proliferation of implausible theories, while its model provides the architecture with the knowledge required for accomplishment of a certain task (Langley, Laird, & Rogers, 2006). Computational cognitive models are runnable, and can be used to test parameters and sequences of human behavior that otherwise could not be tested, such as prohibitive costs or impracticality due to time limits (Byrne, 2002). They also enable making quantitative predictions about users' performance (such as error and learning rates, or transfer of knowledge), which makes them a valuable tool in UI design and usability testing.

In addition to CAs, the integrative approach to UI design also relies on the unification of the levels of interpretation and representation of interactive reality (cognition, theory, methodology, design) via basic cognitive principles. This type of unification reflects the general trend towards minimalism that is currently present in science and in design. However, minimalism itself is only a by-product while the main indicators of a well designed interface are usability and quality in use. The latter two concepts result from a complex process of user-centered design (Schneiderman & Plaisant, 2005). It is generally assumed that usability, together with functionality, reliability, efficiency, portability, and maintainability, determines quality of a software product. Note that there exists another concept—the *quality in use*—that refers to a user's view of the quality of the system containing the software (*ISO 9126-4*). Quality in use may be influenced by any of the six software quality characteristics, but at the same time, it heavily depends on a user, task, and the context of use. Thus, the user-task-artifact triad and the interactive behavior within it directly determine the quality in use. Given the complexity of the human cognitive system on the one side, and that of interactive behavior, on the other, one could claim that usable interfaces cannot stem from the single principle of rational reasoning. Instead, they incorporate other, perhaps more relevant principles of interactive reality.

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