Human-Computer Interaction

An Empirical Research Perspective

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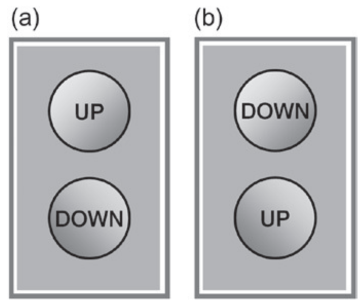

FIGURE 3.18

Button arrangements for an elevator control panel. (a) Correct. (b) Incorrect.

geographic regions have experienced and learned it differently. What is accepted in one region may differ from what is accepted in another.

If there is a physical contradiction, then the situation is different. Consider elevators (in buildings, not scrollbars). Early elevators didn't have buttons to specify floors; they only had UP and DOWN buttons. Consider the two arrangements for the button controls shown in Figure 3.18. Clearly the arrangement in (a) is superior. When the UP control is pressed, the display (the elevator) moves UP. The stimulus (control) and response (display) are compatible beyond doubt. In (b) the position of the controls is reversed. Clearly, there is an incompatibility between the stimulus and the response. This situation is different from the scroll pane example given in Figure 3.6 because there is no physical analogy to help the user (can you think of one?). If all elevator control panels had the arrangement in Figure 3.18b, would a population stereotype emerge, as with the light switch example? Well, sort of. People would learn the relationship, because they must. But they would make more errors than if the relationship was based on a correct physical mapping. This particular point has been the subject of considerable experimental testing, dating back to the 1950s (Fitts and Seeger, 1953). See also Newell (1990, 276–278) and Kantowitz and Sorkin (1983, 323–331). The gist of this work is that people take longer and commit more errors if there is a physical misalignment between displays and controls, or between controls and the responses they effect.

This work is important to HCI at the very least to highlight the challenges in designing human-computer systems. The physical analogies that human factors engineers seek out and exploit in designing better systems are few and far between in human-computer interfaces. Sure, there are physical relationships like "mouse right, cursor right," but considering the diversity of people's interactions with computers, the tasks with physical analogies are the exception. For example, what is the physical analogy for "file save"? Human-computer interfaces require a different way of thinking. Users need help—a lot of help. The use of metaphor is often helpful.

3.4 Mental models and metaphor

There is more to learning or adapting than simply experiencing. One of the most common ways to learn and adapt is through *physical analogy* (Norman, 1988, p. 23) or *metaphor* (Carroll and Thomas, 1982). Once we latch on to a physical understanding of an interaction based on experience, it all makes sense. We've experienced it, we know it, it seems natural. With a scroll pane, moving the slider up moves the *view* up. If the relationship were reversed, moving the slider up would move the *content* up. We could easily develop a physical sense of slider up → view up or slider up → content up. The up-up in each expression demonstrates the importance of finding a spatially congruent physical understanding. These two analogies require opposite control-display relationships, but either is fine and we could work with one just as easily as with the other, provided implementations were consistent across applications and platforms.

Physical analogies and metaphors are examples of the more general concept of *mental models*, also known as *conceptual models*. Mental models are common in HCI. The idea is simple enough: "What is the user's mental model of . . . ?" An association with human experience is required. HCI's first mental model was perhaps that of the office or desktop. The desktop metaphor helped users understand the graphical user interface. Today it is hard to imagine the pre-GUI era, but in the late 1970s and early 1980s, the GUI was strange. It required a new way of thinking. Designers exploited the metaphor of the office or desktop to give users a jump-start on the interface (Johnson et al., 1989). And it worked. Rather than learning something new and unfamiliar, users could act out with concepts already understood: documents, folders, filing cabinets, trashcans, the top of the desk, pointing, selecting, dragging, dropping, and so on. This is the essence of mental models.

Implementation models are to be avoided. These are systems that impose on the user a set of interactions that follow the inner workings of an application. Cooper and Reimann give the example of a software-based fax product where the user is paced through a series of agonizing details and dialogs (Cooper and Riemann, 2003, p. 25). Interaction follows an implementation model, rather than the user's mental model of how to send a fax. The user is prompted for information when it is convenient for the program to receive it, not when it makes sense to the user. Users often have pre-existing experiences with artifacts like faxes, calendars, media players, and so on. It is desirable to exploit these at every opportunity in designing a software-based product. Let's examine a few other examples in human-computer interfaces.

Toolbars in GUIs are fertile ground for mental models. To keep the buttons small and of a consistent size, they are adorned with an icon rather than a label. An icon is a pictorial representation. In HCI, icons trigger a mental image in the user's mind, a clue to a real-world experience that is similar to the action associated with the button or tool. Icons in drawing and painting applications provide good examples. Figure 3.19a shows the Tool Palette in Corel's *Paint Shop Pro*, a painting and image manipulation application.[12] The palette contains 21 buttons, each displaying an icon. Each button is associated with a function and its icon is carefully chosen to elicit the association in the user's mind. Some are clear, like the magnifying glass or the paintbrush. Some are less clear. Have a look. Can you tell what action is

[12] www.jasc.com.

FIGURE 3.19

Icons create associations. (a) Array of toolbar buttons from Corel's *Paint Shop Pro.* (b) Tooltip help for "Picture Tube" icon.

associated with each button? Probably not. But users of this application likely know the meaning of most of these buttons.

Preparing this example gave me pause to consider my own experience with this toolbar. I use this application frequently, yet some of the buttons are entirely strange to me. In 1991 Apple introduced a method to help users like me. Hover the mouse pointer over a GUI button and a field pops up providing a terse elaboration on the button's purpose. Apple called the popups *balloons*, although today they are more commonly known as *tooltips* or *screen tips*. Figure 3.19b gives an example for a button in *Paint Shop Pro*. Apparently, the button's purpose is related to a picture tube. I'm still in the dark, but I take solace in knowing that I am just a typical user: "Each user learns the smallest set of features that he needs to get his work done, and he abandons the rest." (Cooper, 1999, p. 33)

Another example of mental models are a compass and a clock face as metaphors for direction. Most users have an ingrained understanding of a compass and a clock. The inherent labels can serve as mental models for direction. Once there is an understanding that a metaphor is present, the user has a mental model and uses it efficiently and accurately for direction: *north*, for straight ahead or up, *west* for left, and so on. As an HCI example, Lindeman et al. (2005) used the mental model of a compass to help virtual reality users navigate a building. Users wore a vibro-tactile belt with eight actuators positioned according to compass directions. They were able to navigate the virtual building using a mental model of the compass. There is also a long history in HCI of using a compass metaphor for stylus gestures with pie menus (Callahan et al., 1988) and marking menus (G. P. Kurtenbach, Sellen, and Buxton, 1993; Li, Hinckley, Guan, and Landay, 2005).

With twelve divisions, a clock provides finer granularity than a compass ("obstacle ahead at 2 o'clock!"). Examples in HCI include numeric entry (Goldstein, Chincholle, and Backström, 2000; Isokoski and Käki, 2002; McQueen, MacKenzie, and Zhang, 1995) and locating people and objects in an environment (Sáenz and Sánchez, 2009; A. Sellen, Eardley, Iazdl, and Harper, 2006). Using a clock metaphor for numeric entry with a stylus is shown in Figure 3.20. Instead of scripting numbers using Roman characters, the numbers are entered using straight-line strokes. The direction of the stroke is the number's position on a clock face. In a longitudinal study, McQueen et al. (1995) found that numeric entry was about

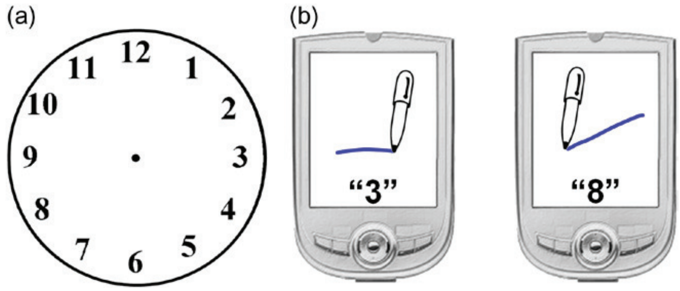

FIGURE 3.20

Mental model example: (a) Clock face. (b) Numeric entry with a stylus.

24 percent faster using straight-line strokes compared to handwritten digits. The 12 o'clock position was used for 0. The 10 o'clock and 11 o'clock positions were reserved for system commands.

Sáenz and Sánchez describe a system to assist the blind (Sáenz and Sánchez, 2009) using the clock metaphor. Users carried a mobile locating device that provided spoken audio information about the location of nearby objects (see Figure 3.21a). For the metaphor to work, the user is assumed to be facing the 12 o'clock position. The system allowed users to navigate a building eyes-free (Figure 3.21b). Users could request position and orientation information from the locator. Auditory responses were provided using the clock metaphor and a text-to-speech module (e.g., "door at 3 o'clock"). A similar interface is Rümelin et al.'s *NaviRadar* (Rümelin, Rukzio, and Hardy, 2012), which uses tactile feedback rather that auditory feedback. Although not specifically using the clock metaphor, *NaviRadar* leverages users' spatial sense of their surroundings to aid navigation. Users receive combinations of long and short vibratory pulses to indicate direction (Figure 3.21c). Although the patterns must be learned, the system is simple and avoids auditory feedback, which may be impractical in some situations.

The systems described by Sáenz and Sánchez (2009) and Rümelin et al. (2012) have similar aims yet were presented and evaluated in different ways. Sáenz and Sánchez emphasized and described the system architecture in detail. Although this is of interest to some in the HCI community, from the user's perspective the system architecture is irrelevant. A user test was reported, but the evaluation was not experimental. There were no independent or dependent variables. Users performed tasks with the system and then responded to questionnaire items, expressing their level of agreement to assertions such as "The software was motivating," or "I like the sounds in the software." While qualitative assessments are an essential component of any evaluation, the navigation and locating aides described in this work are well suited to experimental testing. Alternative implementations, even minor modifications to the interface, are potential independent variables. Speed (e.g., the time to complete tasks) and accuracy (e.g., the number of wrong turns, retries, direction changes, wall collisions) are potential dependent variables.

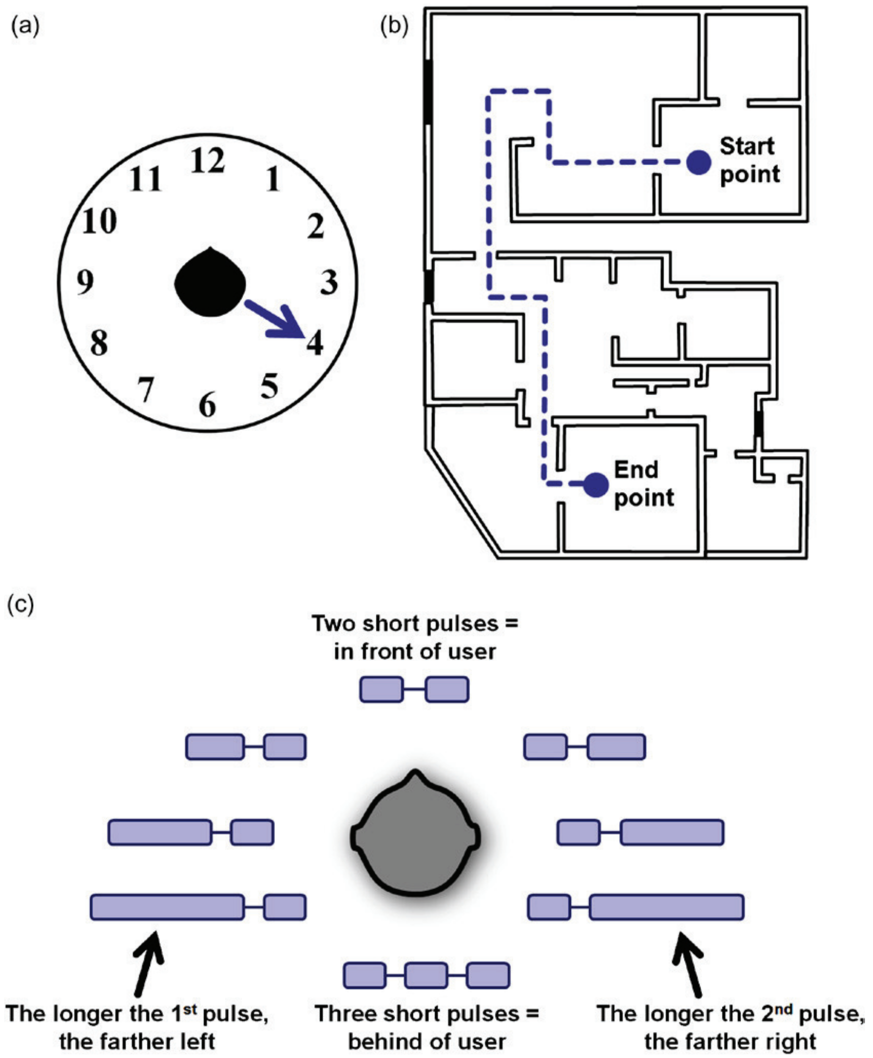

FIGURE 3.21

Spatial metaphor: (a) Auditory feedback provides information for locating objects, such as "object at 4 o'clock." (b) Navigation task. (c) NaviRadar.

(Source: b, adapted from Sáenz and Sánchez, 2009; c, adapted from Rumelin et al., 2012)

Rümelin et al. (2012) took an empirical approach to system tests. Their research included both the technical details of *NaviRadar* and an evaluation in a formal experiment with independent variables, dependent variables, and so on. The main independent variable included different intensities, durations, and rhythms in the tactile pulses. Since their approach was empirical, valuable analyses were possible. They reported, for example, the deviation of indicated and reported directions and how this varied according to direction and the type of tactile information given. Their approach enables other researchers to study the strengths and weaknesses in *NaviRadar* in empirical terms and consider methods of improvement.