Title:

Preschool Children at the Interface: A Cognitive Model of Device Difficulty

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Cognitive modeling is a method by which data on human performance is quantified and interpreted. In the field of human-computer interaction, cognitive models provide theoretical constructs that attempt to identify the mental processing required to perform a given class of computer tasks, and which try to provide explanations for variations in performance across users and across tasks. Many different types of models exist in the current human-computer literature (c.f. Booth, 1989; Olson and Olson, 1990), and have been successfully applied to a range of computer-based tasks, such as word-processing or automatic-teller usage. It is often argued that this type of modeling provides the most profitable way to assess and predict human performance with the computer, and allows the most penetrating insight into the factors that govern effective human-computer interaction.

While cognitive modeling has been a useful technique for characterizing adult computer use, the suitability of this method for understanding the performance of young children is limited. The basic problem is that for such models to have any predictive value, they must assume generally error-free, on-task performance by the computer user, and that the user's performance is always directed toward solving a clearly defined goal (Booth, 1989; Olson and Olson, 1990). Casual use, where there is no clear goal, or use behavior that is filled with errors or digressions, is not well-captured by cognitive models. Unfortunately, such behavior is typical of preschool children, and thus would appear to make cognitive modeling unsuitable for understanding the performance of such children when using a computer.

The present paper takes the position that cognitive modeling can still be a useful strategy for organizing data on children's performance with computers if the domain being studied is appropriately defined. The current model is concerned with the narrow domain of interface devices for cursor control, and their demands on young children as computer users. The purpose of the model is to provide an initial explanation for the results of several studies of children's use of a variety of different input devices, conducted in the past five years at Children's Television Workshop. **This explanation should be regarded as provisional; future studies will attempt to refine the hypotheses presented here.**

The model

The model begins with the view that cognitive development is accomplished by (1) the acquisition of new concepts, and action schemata, in long term memory; and (2) general increases in cognitive processing power, or short-term working memory, that allow these rules to be efficiently recalled and used dynamically in actual situations (c.f. Case, 1985; Pascual-Leone and Ijaz, 1989). This conception of cognitive growth suggests that young children "fail" tasks that older children and adults can solve because (a) they do not know all the concepts required to perform a given task; and/or (b) they may know all the necessary concepts but lack the mental storage space to activate them all together when needed. Under this theory, young children (the focus of the present model) lack both elements of successful performance. They not only may lack the knowledge required to use a given input device - and need to learn it, a task requiring cognitive effort - but they may also lack the working memory to actively utilize all the knowledge they do have.

The domain of behavior being described is children's competence of use, both initially and after practice, of different "pointing" devices, all of which have the common functions of (1) directing a cursor to select icons on a screen; and (2) activating those icons via a confirmatory keystroke or button press. This behavior is considered to have two additive psychological components: The cognitive demands of cursor control as a behavior, and the pragmatic demands, or "rules," of the hardware device itself that must be followed during use. Both of these components require the activation and use of information that must be either learned or drawn from long-term memory, and both components require working memory during their activation and use.

Cognitive demands of cursor control

This model begins from the assumption that the most natural way for a young child to make choices via a graphic interface is through physical actions that are already natural and familiar to the child, in this case: pointing. Pointing to pictures in books, or to desired objects in the store, school, or home, is a behavior established in infancy. It is assumed here that pointing requires no cognitive effort on the child's part: It is an automatic motor behavior whose execution is completely routinized, with no conscious effort required for its performance. In other words, no working memory is required when the child only needs to point to a choice.

Most computer input devices take advantage of pointing as an easy, swift method for making choices. Evaluations of the design and properties of computer pointing devices recognize that these cursor control devices usually conserve various combinations of the three fundamental properties of human movement that play a role in pointing: <u>direction</u>, <u>distance</u>, and <u>speed</u> (Buxton, 1986; Mackinlay, Card, and Robertson, 1990). The mouse, for example, conserves all three properties of the user's physical movement in the cursor. The mouse's motion on the tabletop is precisely mimicked on the screen by that of the cursor, and positioning the mouse is equivalent to pointing a finger at a choice. The joystick, in contrast, only utilizes the direction of the user's movement. Speed is fixed by the machine, and distance is determined by how long the shaft is pressed - not by any actual distance of the user's movement.

For the present paper, it is argued that the less a pointing device conserves the three properties of movement, the more demanding it will be for young children to use. This increase in difficulty as devices become less like pointing is hypothesized to be due to the fact that children must exert more mental processing effort to anticipate, and evaluate, the movement of the cursor when their own movements are not conserved by it, and that this effort increases with each property of their own movement that is not conserved by the input device. In a sense, the less the cursor responds directly to their own actions, the more it moves "independently" of them, and they therefore must allocate more mental resources to monitoring its movement than they would if it were completely mapped onto their own movements. The model assumes that the mental resources (attention to cursor position and motion, planning of cursor movement, etc.) required when an input device does not conserve the child's own movement are significant, and relatively stable - they do not diminish significantly with experience.

<u>Rules of device use</u>

While the cursor's movement on the screen must be attended to, there is another demand the child must attend to: The rules of device use. Every input device must be used in a specific manner if it is to be used successfully. The particular actions that must be performed with the device to move the cursor (sliding a mouse, rolling a trackball, etc.), other specific actions (keeping a device in the correct orientation, pressing a button to confirm a choice), and other cognitive elements (such as translating the directions of movement of the device to the cursor on the screen) vary with the device used.

This model presents the hypothesis that the more such rules a device requires for use, the more difficult it will be for children to use easily and efficiently, because they consume the child's limited working memory capacity in a manner similar to the demands of cursor control itself. However, unlike the cognitive demands of cursor control described above, this model proposes that device rules differ from cursor control in two ways. First, it is hypothesized that these rules require less resources than cursor control. Second, unlike cursor control, device rules are easily assimilated with experience, and they quickly become "chunked," or automated (Case, 1985), ceasing to require active cognitive processing when they are being invoked. In other words, repeated practice with the rules of device use quickly causes them to become habitual and unconscious, so that