The Effects of Practice and Input Device Used on Young Children's Computer Control

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Abstract

The present study investigated the effects of practice on children's ability to use three common computer input devices. Three groups of 3-year-old children used either a joystick, a mouse, or a trackball with a simple graphics-based coloring book program over 5 consecutive days. Children's response times, cursor placement errors, and styles of device use were examined at the beginning and end of the 5 day period. Results indicated that while response times for all three devices declined substantially over the 5 sessions, the joystick had the longest response time both before and after practice. The mouse gave rise to more errors than the other devices on the first day of use. By day 5, the error rate had declined substantially for the mouse, but was unchanged for the trackball and the joystick. Descriptions of children's styles of use over the 5 days indicated a trend toward increasingly refined, adult-like use. Results are discussed with reference to how each device translates different parameters of physical movement into cursor action on the screen, and how these different translations place differential demands on children's cognitive abilities.

Research concerning computers and young children has begun to emerge as a distinct area of developmental psychology. The realization that software for children must be held to standards different from those for adults is reflected in the fact that software reviews have become a regular feature in many educational journals, and that general guidelines for writing and evaluating software for children have been published (c.f. Grover, 1986; Haugland and Shade, 1990;

Lee, 1987). The developmental issues involved in designing appropriate interfaces for children, however, have been largely neglected. Little is known about young children's ability to learn to use standard input devices (the mouse, joystick, etc.) to control a computer program. Such knowledge is critical as graphics-based interfaces become increasingly common in computer software, particularly software for children. Graphics-based interfaces require the user to move a cursor to onscreen icons to make program selections. Thus, children's ability to use different input devices to control cursor movement becomes a fundamental component of *any* software accessibility. The aim of the present study is to examine children's use of three common cursor-control devices (a mouse, a joystick, and a trackball) over time to determine which devices are easiest for young children to learn to use and what properties of each device allow for effective performance.

Most previous studies comparing performance on different input devices have been concerned with adult performance, usually on very specific, job-related computer tasks. Card and his collaborators, for example, compared the mouse, joystick, arrow keys and text keys as methods for selecting text in an online document (Card, English and Burr, 1978; Card, Moran, and Newell, 1983). These studies indicated that the mouse not only had the lowest error rate, but was also the fastest to use, producing response times almost as fast as those observed for processing simple eye-hand coordination tasks. The joystick, while almost as fast to use as the mouse, had almost twice the error rate for the same tasks.

While informative, these studies cannot easily be generalized to the performance expected of young children for two reasons. First, the subjects in the studies were extensively practiced (typically on more than a thousand trials) before being tested for the study; young children typically will not endure this kind of training procedure. Second, young children differ from adults both in terms of cognitive abilities and hand-eye motor performance skills (Wallace, Newell, and Wade, 1978). In our own previous research (Revelle, Strommen, and Offerman, 1990), we examined young children's performance with the mouse, joystick, and arrow keys in their first exposure to the devices. In general, 4-year-olds were more proficient with all of the devices than were 3-year-olds. Both age groups found the mouse and the joystick easier to use than the arrow keys, as assessed by both speed and accuracy.

Trackballs are surprisingly understudied devices, considering their growing popularity as an alternative to the mouse. In the single recent study in which they were assessed, Whitfield, Ball, and Bird (1983) compared the performance and preferences of air traffic controllers using a touchscreen, an offscreen touch tablet, and a trackball to select objects from screens with varying degrees of resolution. They found no meaningful differences among the three devices in terms of speed, but the trackball had fewer errors (failures to select the correct target) at all resolutions. The participants in the study expressed a preference for the trackball relative to the other devices, as well. These results are intriguing, because children's performance using touchpads and touchscreens has been shown to be quite good (Cunningham, 1985; Revelle, Strommen, and Offerman, 1990). Touchpads and touchscreens are, however, typically more complex electronically, and thus in general more expensive and less available than joysticks, mice, and trackballs. If children's performance on the trackball parallels that of adults, the trackball could prove to be an effective, economical interface device for small children.

The present study focuses on children's ability to learn to use three interface devices: a mouse, a joystick, and a trackball. All the devices were employed using the same piece of software over 5 consecutive days, to assess practice effects and to determine the extent to which initial differences among devices in ease of use might be effected by increased familiarity. Such an assessment seems appropriate given the observation by Card et al. (1978) that inexperienced adult users find the mouse very problematic to use, and that their difficulty subsides with practice.

Method

Subjects

Sixty-four 3-year-old children (M = 42.61 months, range 33 to 47 months), drawn from preschools in the Chapel Hill, North Carolina metropolitan area, participated in the present study. The sample had equal numbers of boys and girls.

Materials

Three input devices were used in the study: a mouse, a joystick, and a trackball. All three devices were used with an IBM XT computer. The software used for all groups was the Sesame Street Electric Crayon, *Letters for you* version (Rice, 1987). This program allows children to use a crayon-shaped cursor to color an onscreen picture. The child selects a color by moving the cursor to a colored icon in an onscreen palette, and pressing the device button. To color in a section of the drawing using the selected color, the child moves the cursor to that section and presses the button again. New colors can repaint old ones, providing an open-ended activity.

Procedure

The children were divided into three groups, each using one of the three input devices, with equal numbers of boys and girls in each group. The children used the computer individually, over 5 consecutive days. On *day 1*, the children were introduced to the task. The experimenter told children that they were going to learn to color a picture on a computer, and she introduced the input device by referring to it as a "mover" that could move the crayon on the computer screen in different ways. The children were shown how to both color in objects and change the color of the crayon. After a few practice trials, the children were directed through a 13-trial pretest. The trials consisted of having the child change the color of the crayon, then color in specific parts of the picture. The child was asked to change the color of the crayon (trial 1), color in specific parts of the picture (trials 2 through 7), change the color of the crayon again (trial 8), and then color in several more parts of the picture (trials 9 through 13). On *days 2 through 4*, the children used the software on their own for 15 minutes each day, without adult direction. On *day 5*, the children were given the same test as on day 1, which served as a post-test measure of improvement.

All sessions were videotaped, and children's handling of the devices, comments while using them, etc. were recorded and analyzed. Two quantitative measures of performance were assessed for each trial of the pre- and post-tests: *Response time*, or how long it took the children to complete each trial, and *percent of erroneous placements*, the proportion of trials that children placed the cursor on the wrong region to be colored, or on the "dead" screen areas between the sections of the drawing, which could not be colored.

Results

The pre- and post-test variables were analyzed by summing the response times and the number of errors across trials. The times taken to complete each trial were summed and divided by the total number of trials (13), to yield an average response time score. For the percentage of erroneous placements out of 13 trials, the number of trials on which an error was made was divided by 13, and multiplied by 100 to create a percentage error rate. The means of these two variables for each device on both *day 1* and *day 5* are shown in Table 1.

Response Time

The length of time required to complete a task is one measure of its difficulty. The average response times were submitted to a device x sex x session ANOVA, in which session served as a repeated measure. The results indicated a significant difference among devices, $F(2, 58) = 13.72$, $P < .0001$, a significant difference between sessions, $F(1, 58) = 275.52$, $p < .0001$, and a significant device x sex interaction, $F(2, 58) = 3.63$, $p < .03$. The main effect for device type is due to the children taking the longest time to use the joystick, compared to the other two devices. Both the mouse and trackball were almost two times faster to use, and Tukey post-hoc tests indicate that the joystick time is significantly different from the mouse and trackball times, which are not statistically different from each other. The significant session effect is due to substantial declines in response times for all three devices over the 5 days of the study. For all three devices, children's speed in using them improved considerably with practice,

Table 1.
Mean Differences in Response Time and Error Rates by Device, by Session

Device	Day 1	Day 5	Change
	Average response time per trial		
Joystick	68.25	21.32	-46.93
Mouse	33.73	9.28	-24.45
Trackball	42.92	14.56	-28.36
	Error rates (out of 13 trials)		
Joystick	37%	47%	+10%
Mouse	85%	25%	- 60%
Trackball	31%	29%	- 2%

although differences in response time remain even at session five. The device x sex interaction is due to boys and girls differing in their speed using the joystick and trackball. On both *days 1 and 5,* boys were faster than girls on the joystick (M = 38.52 seconds across both days, versus M = 46.92 seconds for girls), while the girls were faster than the boys in trackball use (M = 22.79 seconds for both days, versus M = 32.78 for the boys). There was no sex difference in speed of mouse use.

Errors in Cursor Placement

The accuracy with which an input device is used is also significant as a gauge of the difficulty of controlling the different input devices. The average error rates were submitted to the same device x sex x session ANOVA design described above. The results indicated a device difference that approaches significance, $F(2, 58) = 2.96$, $p < .06$, a session difference, $F(1, 58) = 8.81$, $p < .004$, and a significant device x session interaction as well, $F(2, 58) = 12.68$, $p < .0001$. The borderline device difference is due to the fact that across both sessions, the three devices average approximately the same number of errors, but with the mouse group's overall mean being higher than those for the other two devices (M = 55% for the mouse, versus M = 43% for the joystick and M = 30% for the trackball). Post-hoc tests comparing error rates for both sessions indicate that the mouse error rate in the first session is significantly different from the joystick and trackball error rates, which do not differ from each other. At the fifth session, however, no significant differences in error rates exist. Thus, the main effect for devices may partially reflect the significant device x session interaction. As Table 1 indicates, in the first session pretest the children using the mouse experienced a much higher number of errors than those using either the joystick or the trackball. By the fifth session post-test, however, the error rate for mouse users had decreased to the same range as error rates for the trackball and joystick users, which did not change significantly over time.

Descriptive Results

Joystick use. Of all the devices, children have the most difficultly controlling the joystick. To operate a joystick, the shaft has to be held rigidly in one position, and then released when the cursor is on the target. The children found it hard to change direction while moving, often directing the cursor far from their target before finally succeeding. It seemed that having to follow and correct the trajectory of the moving cursor required a refined response style that was beyond the capacity of many of the 3-year-olds in our sample. Even with the increased control that came with practice, the children still frequently "overshot" their targets by releasing the shaft too late and allowing the cursor to move off the goal. Often, they failed to notice this fact, and pressed the button to select the target anyway, resulting in errors.

Mouse use. The children were relatively quick with the mouse on the first day, but they were the most inaccurate with its use, committing almost one mistake per trial. By *day 5*, however, they gained in both speed and accuracy, using the mouse quickly and with many fewer errors. It seemed that the high initial error rate was the result of the mouse's one-handed mechanism, which requires that the cursor be moved and the button be pressed with the same hand. The high number of errors on the first day was due to children inadvertently moving the mouse (and the cursor) as they pressed the button to color an area. This action moved the cursor off the target. With practice, they quickly gained enough control over their movements to overcome this problem, as indicated by the declines in both response time and error rates.

Trackball use. Of the three groups, the trackball users showed the best overall performance on the pretest, with greater speed than joystick users and higher accuracy than mouse users. The early accuracy with the trackball appears to result from its being fixed to a stable base. Unlike the mouse, pressing the button could not move the device and disturb the cursor's position. The trackball seemed to allow children tighter initial control of the cursor than was the case with either the joystick or the mouse.

Button Pressing

One feature that all three devices have in common is the presence of at least one button. Across all three devices, children's performances on the buttons were consistent in two aspects that are worth noting. The first is the tendency of the children to hold down the selection button when making a choice. No matter which device was used, the children tended to press and hold down the button for several seconds to register a selection. Second, the children frequently press the button for no reason, occassionally when moving but usually when the cursor is stationary and they appear to be deciding what to do next.

Discussion

The results of the present study provide evidence that (1) different input devices show significant differences in ease of use for young children, and (2) substantial practice effects exist for all three devices. The joystick is clearly the least effective device for young children to employ. It requires the longest time per trial both initially and after 5 days of practice. The trackball and mouse, in contrast, are both used by young children quite easily and effectively. The trackball is fast, with a low error rate that remained low across the 5 days of the study. The fact that children started with initially low errors on this device suggests that it is the easiest device to use "cold," or with a minimum of experience. The mouse, in contrast, was not significantly different from the trackball in terms of speed, but had an initially high error rate due to difficulties in coordinating the movement of the mouse with pressing the buttons to select onscreen targets. This high error rate drops dramatically with experience, however, and should not be considered a serious impediment to young children's ability to use a mouse as an input device.

Why should the mouse and trackball show such superior results relative to the joystick? Our provisional hypothesis is based on the idea, advanced in informal terms separately by Card, et al. (1978) and Buxton (1986), that different types of input devices preserve different aspects of the user's hand movement onto the cursor movement on the computer screen. Card et al. suggested that the mouse was the fastest, most accurate device used in their study because "less mental translation is needed to map intended motion of the cursor into motor movement of the hands than for the other devices (p.612)." Buxton (1986) has suggested a similar analysis for the trackball, arguing that the trackball allows direct "motion-motion mapping" of all three dimensions of the child's hand and arm movement (direction, speed, and distance travelled) directly into cursor action on the screen. The joystick, in contrast, only allows "position-motion" mapping; only the direction of cursor movement is under the user's control. In other words, for the mouse and the trackball when the user moves, the cursor moves and when the user stops, the cursor stops. With the joystick, the user must move the shaft to a particular position and *hold it* there to make the cursor move. Adult users are clearly capable of both "motion-motion" and "position-motion" mapping, so determining which interface is optimal depends on the task being performed (Buxton, 1986). For young children, however, the cognitive demands of the extra "translation" required to use the joystick, relative to the mouse and trackball, combined with the task demands of using any computer software, may exceed their processing abilities.

In future studies, at least two obvious areas of inquiry follow from the present results. The current study indicates that given relatively open-ended software tasks, the mouse and trackball are superior to the joystick for young children. One immediate goal should be to develop a more precise analysis of cursor control, in terms of the physical and psychological requirements of different cursor-control tasks. Such an analysis would help refine our ability to characterize the properties of different input devices, and assess their match to the demands of particular tasks. When selecting items from a menu, for example, is it easier to make choices using a cycle-and-choose interface, or is a mouse preferable? A second area of inquiry should be a more careful assessment of the cognitive processes involved in joystick use. Such an assessment would be of both theoretical and practical interest, illuminating as it would the developmental issues that relate to cursor control performance. Knowing which aspects of cursor control are most demanding for young children, and how they change with age, would be valuable to both child development researchers and to the designers of software for educational use.

In conclusion, the present results indicate that young computer users experience differences in ease of use across different input devices, and that while performance improves with experience for all devices, differences are still evident after 5 days of continuous use. These differences in device use appear to be based on developmental cognitive factors, and possibly interact with software factors to either facilitate or impede young children's ability to make effective use of computers. By systematically studying how young children employ input devices, and under what conditions they achieve the most success, we can provide a solid empirical and theoretical underpinning for the development of children's software and hardware. Moreover, by minimizing the processing required to manage the interface, we can help focus children's resources on the educational content of software activites.

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