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This button makes you go up: three-year-olds and the Nintendo controller*

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Forty three-year-old children used the Nintendo controller in a simple cursor-placement task, with two different software interfaces. The directional interface required children to map specific directions of movement on to specific buttons on the controller. The non-directional interface simply advanced the cursor in a clockwise direction to the next placement location, regardless of the specific directional button pressed. Results indicate that while the youngest three-year-old children find the non-directional interface slightly easier to use, older three-year-olds are more successful with the directional interface. In addition, all three-year-olds actually experienced problems using the simpler, non-directional interface – and problems increased with age. The results are discussed with reference to designing appropriate interfaces for the wide variety of skill levels present in the pre-school population.

Keywords: Interface, preschoolers, cognitive development

Introduction

Consumers have long been able to buy children's educational software for their home computers. The past few years have also seen the introduction of educational titles for video game systems. *Sesame Street* successfully used the medium of television to bring educational opportunities to preschoolers at home. In the same way, video game systems such as the Nintendo Entertainment System (NES) have recently begun to be exploited as platforms for providing home educational experiences for preschoolers as well. Children's Television Workshop (CTW), makers of *Sesame Street*, have produced four Nintendo cartridges[1–4], and the toy company Fisher-Price has also begun to produce such products[5,6]. The advent of such products is laudable, but they raise significant cognitive issues because they require very young children to use the NES controller, which is an input device designed for a much older user population.

The NES controller is a small, hand-held plastic input device measuring 120 × 50 × 16 mm. A crosshair button and two selector buttons are used to move a cursor, usually in the form of a small figure, on the television screen (see Figure 1). The crosshair button is shaped like a plus sign or cross, and each arm corresponds to one of four directions: up, down, left, and right. The arms are all part of a common button, but operate in a manner analogous to keyboard arrow keys: pressing each arm of the button makes the character/cursor move in the direction pressed. The correspondence between directions of movement and the arms of the crosshair means that, for proper use, the device must always be held lengthwise so that the arms match their appropriate directions. The two red selector buttons serve various functions, depending on the game being played. Typically, one makes the character jump, and the other registers a game-specific response when needed.

Can young children use the NES controller to direct cursor movement? Such a question raises both cognitive and physical human factors issues. The NES controller has the virtue of a simple, intuitive design that provides a direct spatial correspondence between the four

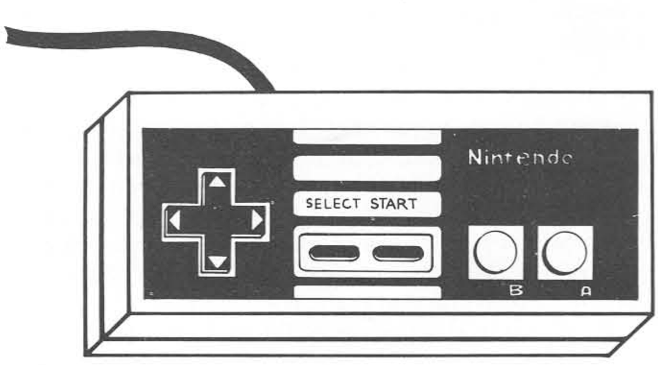

Figure 1 The standard input device for the Nintendo Entertainment System

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directions of movement and the arms of the crosshair button that produce those movements. Do preschoolers have the representational ability to appreciate this correspondence? And if they do, can they appreciate the larger rule that the correspondence between direction of movement and button is only conserved if the controller is held in the correct orientation relative to the television screen? The only way to find answers to these questions is to have children use the controller in an experimental setting where their performances can be carefully assessed.

A second area of interest is that of alternatives to directional control. Given the existing base of installed Nintendo machines in the USA, it is clear that special input devices will not be available for pre-school users. If young children cannot use the directional control for which the NES controller was designed, what sort of alternative interfaces might be used? The present study addresses these issues by comparing children's performance using two different interfaces to the NES controller. One interface requires directional control, and the other does not. The results reveal a complex interplay of development and learning, such that each interface is appropriate to a distinct population at different points during the third year of life. This finding poses a special paradox for designers of interactive learning systems for the pre-school population, and possible design strategies to address this paradox will be considered.

Method

Subjects

Forty children (mean age 41 months) participated in the study. They were divided into two groups of 20, according to the type of interface they were tested with, and matched within and across groups for age and sex. A younger age group was defined as 36–42 months and an older as 43–48 months. Only children whose parents reported no experience with computers or Nintendo game systems were included in the sample.

Materials

The first and lowest-level game on *Big Bird's Hide & Speak*[3] was used as the task. In this game, children must use the crosshair button to move the cursor (a small bird) to one of four windows (two above, two below) in a brownstone home pictured on the screen. A different Muppet sits in each window, and Big Bird asks the child to find them one at a time: ie "Find Ernie", "Find Grover", etc. After moving the cursor to the desired window, the children press either of the red function buttons to select it. If the selected Muppet is wrong, a tone indicating an incorrect response sounds, and the Muppet shakes his head. Big Bird then says the correct name of the selected Muppet and repeats the target Muppet: eg "That's Grover. Find Ernie." When the correct Muppet is located, Big Bird gives an approving response and then prompts the child to find a new Muppet: "Hooray! You did it! Now, find Bert." Cursor movement is restricted to the four windows, and each round of game play ends only with the selection of the correct Muppet.

Two versions of the software were used, each utilizing a different form of cursor control. In the non-directional version, the cursor simply moved in a clockwise direction through the four windows. Pressing any portion of the crosshair button resulted in a movement to the next window in the sequence. In this way, the cursor simply cycled from window to window one at a time, in a circular pattern, with each button press. All the child needed to do was watch until the cursor was on the appropriate window, and then press the red button.

In the directional version, the cursor's movement could be directed by pressing the appropriate arm of the crosshair button. Pressing an arm of the crosshair moved the cursor to the window in that direction, but only if movement in that direction was possible. If the cursor was in the lower right-hand window, for example, it could only move left to the lower left window, or up to the upper right window. Movement to the right or down was not possible. If the child pressed an invalid direction, a tone identical to the incorrect answer tone sounded and the cursor did not move. Thus, in this interface children had to decide on an appropriate direction of movement and then execute it by pressing the corresponding arm of the crosshair button in order to reach the target Muppet.

Procedure

Each child played one of the two versions of the game individually, in a room near their classroom. The children were introduced to the NES controller in the following ways.

Users of the non-directional version were told, "See that little bird by the window? This big black button makes him move to the next window! Watch." (Researcher demonstrates.) "Now you move little bird! Press the big black button and move little bird to the window where (character) is."

Users of the directional version were told, "See that little bird on the window? This black button has little arrows to make him move in different directions! You choose which way you want the little bird to move, and press the arrow that points that way. See, if I press the down arrow he goes down. If I press the up arrow, he goes up! You do it! (The child was encouraged to move the cursor). If I want him to go towards (character on right) I press this arrow. If I want him to go towards (character on left) I press this one. You try it! Now, you have to make the little bird go to the window where (character) is." When children tried to move in an invalid direction, they were told "Oops! See, you can't move that way. You have to go to a window with a person in it."

In both conditions, when the cursor was placed on a Muppet, the child was told, "Now press a red button to show you're ready! You can press either one, because they both do the same thing." Regardless of the version of the game, children play four games, or 16 trials. All trials were videotaped for later scoring, with the screen image captured as an inset in the camera image of the child.

Results

Scoring

The first trial of each session, which was used to introduce children to the task and to the NES controller, was not used in the analysis. Only the subsequent 15 trials were accepted as data. The children's performance was assessed on six measures as follows.

Average number of extra movements per trial. For each trial, the shortest number of necessary moves (SNM) between the starting position of the cursor and the goal Muppet was computed. The SNM was subtracted from the total number of moves actually made on each trial, yielding the number of extra movements made on that trial. These values were averaged across the 15 trials to produce the mean number of extra moves made before the red button was pressed on the correct Muppet.

Percentage of trials with lost opportunities. This was the percentage of trials during which the cursor moved on to and off the correct Muppet at least once, prior to the red button being pressed on it.

Percentage of trials with one or more wrong Muppets selected. This was the percentage of trials during which the child pressed the red button on the wrong Muppet at least once.

Orientation of the NES controller during use. The way children held the NES controller during use was scored for each of the 15 trials in both conditions. For each trial where the controller was held in a non-standard manner (upside down, sideways, etc.), children were also scored for whether they spontaneously corrected themselves or if they required adult intervention.

The next two measures were specific to the non-directional interface.

Percentage of trials with rapid button pressing. This is the percentage of trials on which children demonstrated rapid, repeated pressing of the black button while moving the cursor. This behaviour was a strategy to increase the speed of the cursor's passage through the Muppets, in order to reach the desired target.

Percentage of trials during which children attempted to use the crosshair button in a directional manner. This was defined as the child's pressing a specific arm of the crosshair button in an attempt to move the cursor in that direction. To be scored on this variable, the child had to do one of two things. First, they could state explicitly that they were trying to use the arm of the button in this way (this usually occurred in the form of a complaint or question). Second, they were scored as using the crosshair in a directional manner if they (a) clearly pressed just one arm of the crosshair button, and (b) the arm they pressed would move them in a valid direction, towards the target Muppet.

The children's performance

Average number of extra movements, percentage of trials with lost opportunities, and total "wrong Muppet selected" trials were analysed using 2 (interface type) × 2 (sex) × 2 (age group – younger three-year-olds, older three-year-olds) ANOVAs. Means and standard deviations for all measures on each subgroup (interface type by age group) are given in Table 1. However, analyses of interest largely concern interactions. For average number of movements, the only significant effect was an age group × condition interaction: $F(1, 32) = 7.40$, $p < 0.01$. Post-hoc comparisons using Tukey's HSD tests indicate that the average number of extra moves of the young three-year-olds in the directional condition (5.31 moves per trial) is significantly different from means for all three other groups (1.45 extra moves for the younger threes/non-directional condition; 2.88 extra

Table 1 Means (and standard deviations) for all measures

	Non-directional interface		Directional interface	
	Age group		Age group	
Measure	$\leqslant$ 42 months $n = 10$	$>$ 42 months $n = 10$	$\leqslant$ 42 months $n = 10$	$>$ 42 months $n = 10$
Extra moves per child over 15 trials	1.45 (1.46)	2.88 (3.62)	5.31 (5.30)	0.88 (0.56)
Lost opportunities per child[a]	0.04 (0.11)	0.20 (0.27)	0.05 (0.09)	0.04 (0.08)
Wrong Muppet selected per child[a]	0.45 (0.32)	0.46 (0.28)	0.33 (0.31)	0.15 (0.19)
Controller used out of orientation[b]	0.50	0.20	0.50	0.40
Rapid pressing per child[a]	0.09 (0.15)	0.24 (0.24)		
Crosshair used directionally per child[a]	0.41 (0.32)	0.21 (0.17)		

[a] Reported as the proportion of trials on which this event occurred
[b] Reported as proportion of children in sample

moves for the older threes/non-directional condition; and 0.88 extra moves for the older threes/directional condition). Only younger children using the directional interface required many more moves before reaching their targets; younger children using the non-directional interface performed in a manner comparable to older children in both conditions.

For the percentage of trials with lost opportunitites, the only effect to approach significance is the age group × condition interaction: $F(1, 32) = 3.40$, $p < 0.07$. An examination of the means, however, reflects an almost opposite result to that for the average number of extra moves. The younger children misdirected the cursor on to and off the correct target in approximately the same percentage of trials in both conditions (4% in the non-directional condition and 5% in the directional). The older children, in contrast, misdirected the cursor on 20% of trials in the non-directional condition but only 4% of trials in the directional condition.

The results for number of wrong selections indicate a significant main effect only for condition: $F(1, 32) = 5.51$, $p < 0.025$. Once again, the non-directional interface was problematic, giving rise to more trials with errors, 46% against 24% for the directional interface.

Why should the non-directional interface give rise to more lost opportunities and wrong selections? The answer appears to lie in the consequences of a behaviour unique to the non-directional condition: rapid button pressing. The percentage of trials during which rapid button pressing occurs is correlated with age in months: $r(20) = 0.45$, $p < 0.05$. Rapid button pressing is also correlated with lost opportunities ($r(20) = 0.43$, $p < 0.05$), which are correlated with wrong selections ($r(20) = 0.47$, $p < 0.04$).

These relationships suggest the following. As age increases, children resort with increasing frequency to rapidly pressing the crosshair button. The goal of this behaviour is to cycle the cursor rapidly through the Muppets to reach the target as swiftly as possible. However, a side-effect of rapid button pressing is an increase in lost opportunities for selecting the correct Muppet, because children fail to stop pressing the crosshair button in time, and accidentally overshoot the target. The lost opportunities, in turn, often result in wrong Muppet selections because the children, in their eagerness, press the red buttons while the cursor is still moving and accidentally register the wrong Muppet as their choice.

The last measure concerns children's reactions to the NES controller as a directional input device, when used in a non-directional manner. Are children inclined to try to use the crosshair button in a directional manner, even when their experience indicates that it does not direct the cursor in that way? The percentage of trials in the non-directional condition during which children tried to use the crosshair button in a directional manner at least once showed a significant effect only for sex; 17% of trials for girls and 45% for boys: $F(1, 19) = 6.44$, $p < 0.02$.

In terms of keeping the device in the correct orientation, 35% of the children in the non-directional condition and 45% of children in the directional condition turned the controller sideways or upside down during use. Two of the children in the non-directional condition re-oriented the controller by themselves, but correcting how the controller was held was unnecessary. This behaviour had no effect on the children's use of the non-directional interface since there was no correspondence between directions on the screen and the device, and hence their performance was not affected. However, children in the directional condition immediately experienced problems, discovering that the cursor would not move in the direction they desired. The most common interpretation by the children was that the game was "broken" or "didn't work anymore". Only one child spontaneously corrected the problem by re-orienting the controller. The remaining children had to be told by the researcher how they could fix the problem.

Conclusions

The issue addressed in the present study was whether or not three-year-old children possess the cognitive competence to use an interface that relies on directional input in order to move a cursor, and whether an alternative, non-directional interface would result in superior performance. The results of the study suggest that older three-year-olds are able to map direction of movement on the screen on to specific buttons quite easily. Only the youngest three-year-olds had difficulty using the directional interface, as indicated by the number of extra moves they required to place the cursor on the target. It is notable that these children nonetheless succeeded in eventually moving the cursor to the target accurately, as indicated by the fact that a higher number of errors is actually associated with the non-directional, rather than the directional, interface. The directional inteface thus appears to be hard for the youngest children to use, but given the present task it does not seem to present insurmountable barriers to cursor control. The only complication that the directional interface does provide is that the controller must be kept in the correct orientation for use. Children rotated the controller during use in approximately equal numbers in both conditions, but the disruptive effects of this rotation in the directional condition, and children's inability to relate them to the misorientation of the controller, suggest that this is a significant added constraint on children's use of the directional interface.

The most striking finding of the study, however, concerns the elevated levels of lost opportunities and wrong selections associated with the non-directional interface. While this interface was originally hypothesized to be easier for children to use because it does not require directional representation, it now appears that too simple an interface raises its own problems. As was noted in the results, children's impatience with the deliberate, step-by-step movement of the non-directional cursor led them to adopt a strategy of rapidly pressing the crosshair button to propel the cursor swiftly to the target. While adaptive, this strategy resulted in more lost opportunities and, indirectly, more errors. Thus a simple interface that appears to have advantages for the young three-year-old soon becomes, with familiarity and cognitive growth, inadequate for the same child only a few months later.

Added evidence of the limited utility of the non-directional interface comes from the fact that 31% of the sample spontaneously tried to use the crosshair button in the directional manner for which it was designed. The fact that more boys than girls attemped this performance should not be construed as indicating that boys are more competent than girls in cursor control. The sex difference could reflect a variety of factors unrelated to cognitive competence. Boys may have more experience with the NES, even without owning one, than girls; or they may simply be more willing to experiment than the girls. Whatever the cause of the sex difference, the fact that almost one third of the sample tried to use the non-directional NES controller in the directional manner suggests that even children identified as having little or no NES or computer experience possess the basic ability to recognize and exploit directional information in cursor control.

The present results establish that young children can use directional interfaces with the NES controller, and that a non-directional interface, while simple and useful for very young children, quickly outlives its usefulness with older children. These conclusions must be qualified by the nature of both the particular interfaces tested and the nature of the target population of users. The directional interface only required children to indicate their direction of movement; it always stopped on the nearest possible object. For many directional interfaces, the screen is simply an open field where the cursor can travel anywhere on the screen, even though the active objects are only small, specific icons located within the larger screen environment. This situation would require children to monitor the progress of the cursor and stop it precisely within the object's boundaries in addition to selecting the direction of movement. It is not clear that this is easy for children. Two studies that tested this type of interface with computer joysticks as the input devices reported that three-year-olds had significant difficulties[7,8]. Conversely, it is not clear that all non-directional interfaces would raise similar problems to the one tested here. What is clear is that under favourable conditions, very young children can use a directional interface with the NES controller.

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