Educational software for children: analysis of interaction techniques for direct manipulation.

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RESUME

Dans cet article, nous nous intéressons à l'utilisation de styles d'interaction de manipulation directe avec la souris par les enfants lors de l'utilisation de logiciels éducatifs. Nous souhaitons évaluer l'impact du choix du style d'interaction sur la performance des enfants lors de l'utilisation d'un logiciel éducatif à modèle d'apprenant ouvert (OLM). Nous présentons les résultats d'une première étude réalisée avec une classe de CE2 (24 enfants, 7-9 ans) comparant deux styles d'interaction, pointer-et-cliquer et pointer-et-sélectionner, en utilisant Multipliotest, un logiciel éducatif avec OLM qui a pour but d'aider les enfants à apprendre comment multiplier.

MOTS CLES : Conception de l'interface, techniques d'entrée des données, ingénierie éducative, pointer-et-cliquer, styles d'interaction, enfants, interaction avec la souris.

ABSTRACT

This paper is concerned with the investigation of children's use of direct manipulation mouse interaction styles when using educational software. The results of an experiment comparing two interaction styles (point-and-click and point-and-select) are presented. The context for the study relates to OLM educational software, 'Multipliotest', aimed at assisting children's learning of multiplications in French primary schools. A class of 24 children (aged 7 to 9 years old, level CE2) played two versions of this multiplication game, each version utilizing a different interaction style.

CATEGORIES AND SUBJECT DESCRIPTORS: H.5.2 [Information Interface and Presentation]: User Interfaces – Input devices and strategies; Interaction styles; Evaluation/methodology; K.3.1 [Computers and Education]: Computer uses in Education.

GENERAL TERMS: Experimentation, Human Factors, Measurement, and Performance.

KEYWORDS: Interface design, input techniques, computers in education, point-and-click, interaction styles, children, mouse interaction.

INTRODUCTION

With the wide distribution of games and other applications on the Internet, as well as the deployment of technology-enhanced applications for education into primary schools, children the world over are becoming more familiar with using computers and computer-based applications from an early age. Researchers in Child-Computer Interaction, and Interaction Design for Children, have investigated how children use technology in order for designers to produce software suitable for efficient use by children. In this context, studies have been investigating different interaction techniques used in children's software. Whilst children appear to adapt to whatever interaction style (IS) is used, some issues remain as to their level of precision in pointing tasks, and their ability to use the mouse in order to fulfil the tasks required by a specific IS [2,4].

Interaction is a fundamental part of a computer-based application. Understanding which interaction style improves usability for children is of great research interest. While a wide range of other input devices (pen-based, touch-based, etc…) are investigated and included into current learning technologies, the standard tools present in classrooms and at home remain mouse-based input devices [3]. Therefore, this research agenda and studies concentrate on using direct manipulation techniques, with mouse-based input devices.

In the 1970s and early 80s with non computer-based studies undertaken by psychologists [5], and then in the 90s with computer input device investigations [2], studies clearly showed that pointing performance increases with age during childhood. These results motivated researchers in defining interaction methods specifically designed for children's developing skills. The aim of numerous studies has been how children appropriate various types of interaction styles within direct manipulation, with children from different backgrounds, experience in using computers prior to the studies, and age groups. A few are outlined here: Berkovitz [1] illustrated the difficulties for children aged 6 to 12 years old to manipulate “Marquee Selection” techniques. Issues relating to accuracy of pointing tasks for younger children [2], mice sizes [3], or maintaining pressure on the mouse-button for a prolonged amount of time have been investigated. Inkpen’s study on the drag-and-drop versus point-and-click techniques with children aged 9 to 13 years also showed accuracy problems in dragging and pointing tasks [4]. In this paper, we are interested in investigating the usability of two commonly used interaction styles: point-and-click, and point-and-select.

METHOD

The experiment involved children using versions of Multipliotest with either a point-and-click IS or a point-and-select IS. During the first iterations of design of Multipliotest, the participatory-design teachers defined point-and-select as the primary interaction style to answer questions, allowing children to compose numbers by iteratively selecting digits. However, since point-and-click IS was found to be better when compared to other IS [1,4], we chose to study the impact of these interaction styles on children’s achievement, preference, speed and accuracy of answer. 24 children from the class (aged 7 to 9 years) of level CE2 participated in the study by playing two versions of the software. Each child used both versions of the software, with a 24 hours gap, the activities in between sessions excluding any mathematical content. The order of experiencing the different IS was counterbalanced.

Hardware and Software

All three computers used were Macintosh Mac Book portable computers (Colour 13-inch screens), with a ‘two-buttons’ mouse. Most of the interactions with the software were undertaken using a mouse, with the exception of the login procedure, which required the use of the keyboard. While all children had a two-button mouse, the three mice used were not identical size-wise. However, Hourcade et al’s [3] investigation of the impact of mouse size on accuracy and efficiency of pointing tasks did not reveal any significant difference. It is therefore unlikely that most of our participants would perform differently given different mouse sizes.

Procedure

The children were assigned to a group of 3. Each group used a version of the software for 20 minutes, supervised by a researcher. A short introduction to the game and the experiment was undertaken prior to the experiment in front of the whole class. Once logged-in, the children were free to use the software by choosing the multiplication tables and levels to try and master. The researcher was monitoring the learning session, and helped the children when the questions were related neither to multiplications nor interaction. During the session, the computer recorded the time for movements, as well as the number of interaction errors whilst giving an answer. Once the 20 minutes were over, they went back to class for another group to take their place. The next day, the same groups were asked to come again for another session, each child using the IS they did not use the first time. At the end of the experiment, the children were asked to rank their preference for IS using a 5-points smiley-o-meter [6]. For each IS, the child had to define how much s/he found it useful for giving answers.

Two interaction styles for one task

Multipliotest, developed in collaboration with French teachers and primary school children, contains three activities in order to learn how to multiply and to revise multiplication tables. In this study, children could interact with and change their user model, revise their multiplication tables, and choose the test they want to do (restricted to level 1 – one multiplication table - and 2 – all multiplication tables from 1 to 10 - because of their limited knowledge of multiplication tables at the time of the experiment.) The comparison of interaction styles within Multipliotest was related to one key task in the game: giving the result of a multiplication. Children from school level CE2 learning multiplications for the first time still break down numbers into columns, describing them as a succession of digits: units (U), tens (T), hundreds (H), … For this reason, the software asks the children to give an answer by selecting the number corresponding to each of the digits of the answer. The differences produced by the two IS, lies in the validation of the digit to modify, and the selection of the actual number given for said digit. In the point-and-click version, the children first click on the icon selecting the column considered, before moving the mouse over the calculator to select the digit corresponding to the column. In the point-and-selct IS, the children also click on the column to modify, opening a sliding bar for this column, and then slide the highlighted number vertically until they reach the digit desired. Both versions of the software require the same number of clicks with the mouse (two for each digit modification and one for the validation), and changes within the interface. The widgets used for both IS were equal in size, and always fixed in position on the screen. However, while for point-and-select, the selection occurred where the digits columns were, for the point-and-click interaction, the calculator was on the right part of the screen, separated from the answer area.

Design of the experiment

In this experiment, we manipulated one independent variable, the mouse interaction style (two levels: point-and-click, and point-and-select). The questions to be answered in each version of Multipliotest were identical, except for the IS used to answer. Each child used both versions of the software, one group beginning by the point-and-click version, and the other by the point-and-select version. The children were randomly assigned to one of the two groups, but their mathematical abilities in regards to multiplications were taken into account for the two groups to be balanced.

Four dependant variables were measured: children's achievement; preference; overall movement time; and interaction errors. The results concerning children's achievements, overall movement time, and interaction errors were analyzed using a two-sample correlated T-Test with 23 degrees of freedom. The null hypothesis states that there is no difference in IS concerning the dependant variable. The alternate hypothesis is that the IS impacts on the results of the dependant variable.

RESULTS

Achievements

Table I show the number and percentage of children answering none of the questions successfully, and Table II the number of questions answered correctly.

Condition	Count	Zero correct	%
Point-and-click	24	1	4%
Point-and-select	24	8	33%

Table I: Number of children who were unable to solve any question.

Of all the children participating in the study, 33% of them were not able to answer any question correctly when using the point-and-select version, and only 4% in the point-and-click version of the game. As there was no difference in mathematical difficulty of the questions to be answered for both IS, it seems that the problems of use of the IS had some impact on their ability to answer questions: while they knew the answer in most cases, they were not able to enter it, and preferred to pass the question after struggling too long.

Condition	N	MEAN	SD
Point-and-click	24	2.18	1.80
Point-and-select	24	1.416	1.61

Table II: Number of questions correctly answered

While all children answered between 0 and 6 questions correctly, when using the point-and-click interaction style, they were able to perform significantly better than in the point-and-select condition, t (23)=8.577, p= 0.001.

Overall Movement Times

The average movement times for the two interaction styles are shown in Table III. Only questions where no error occurred were included in the means. When using the point-and-select IS, children were found to take a significantly higher number of seconds to perform the task, t(23)=20.783, p= 0.001.

Condition	N	MEAN	SD
Point-and-click	24	6.58	1.81
Point-and-select	24	27.2	3.27

Table III: Overall movement time

Interaction Errors

The average number of errors for each interaction style is shown in Table IV. The analysis revealed that the point-and-select IS led to children committing a significantly higher number of interaction errors, t (23)=11.281, p= 0.001.

Condition	N	MEAN	SD
Point-and-click	24	0.66	1.62
Point-and-select	24	6.66	2.76

Table V: Number of interaction errors

Preferences

Children's preference of interaction style can be grouped into three nominal categories: *prefer point-and-click*, *no preference*, and *prefer point-and-select*. 87.5% of the children preferred the point-and-click IS (21/24), 8.3% had no preference (2/24), while only 0.4% preferred point-and-select (1/24) as it required less mouse-movement across the screen.

DISCUSSION

Impact on learning

The results from Table I demonstrate that a point-and-click interaction style, used in an interactive learning environement, can be more effective in terms of performance than a point-and-select IS. While one could argue that the knowledge of multiplications might have evolved during the 24 hours gap, and influenced by the first use of the software, the data was counterbalanced in that aspect as half of the children began with point-and-click, while the others began with the point-and-select version. No effect was found in the order in which the versions were used. However, as this experiment manipulated the styles within a rich, complex environment, some other factors might have interfered with the results.

Overall Movement Times and Interaction Errors

The results of the experiment highlight that point-and-click is a more effective mouse IS than point-and-select, both in terms of speed and accuracy. The movement time results included only the questions in which no interaction errors occurred. While these results demonstrated that the point-and-click interaction style was faster than the point-and-select interaction style, the children made errors in approximately 26% of the questions. By including those questions in which errors occurred, differences between the movement times for point-and-click and point-and-select increased significantly, t (23)=47.359, $p < 0.001$. Instead of an average difference of 36ms between the two interaction methods, the average difference increased approximated 230% with the point-and-select interaction style becoming on average 120ms slower than the point-and-click IS.

The errors due to the interaction were mainly due to the selection within the point-and-select version. Children indeed had difficulties moving the mouse down the list of numbers to accurately select the number they wished to choose. Observations from the study showed that the level of frustration increased along with the use of this version of the interface. This resulted in children missing questions rather than trying to select the correct number. The number of errors in this version may also be linked to the representation children had of the task. In the point-and-click version, they were familiar with the metaphor of the calculator, used to visualize all numbers at once and select one among them. In the select version however, they had to "uncover" the number, and select it in a more precise manner. Furthermore, the point-and-select IS can be related to the drag-and-drop IS as it requires persistent pressing of the mouse in order to go on the digit chosen, and then let go of the mouse button. In the point-and-click IS, children had more flexibility of movement between selecting the column to modify, and the digit to enter.

Preferences

Children who used the point-and-select version first were more decisive in their ranking of the interaction style, and selected the extremes in both scales (extreme positive for point-and-click, and extreme negative for point-and-select). Many children who preferred the point-and-click interaction style explicitly stated that they found the point-and-click easier, as when they had problems guiding the mouse to the selection area, they could try again more easily with this IS. They also complained that the point-and-select interaction style "gave them wrong answers".

CONCLUSION AND FUTURE WORK

Our results investigate the usability of the point-and-click and point-and-select interaction styles. The investigation took place within a field study which focused on investigating children's natural interaction whilst playing two versions of an OLM learning environment, Multipliotest, where each version only suported one interaction style. The results highlighted that point-and-click is a more effective mouse interaction style than point-and-select for children aged 7 to 9 years, in terms of achievement, interaction error, speed and accuracy of answers, and children preference.

However, those results only represent one snapshot of effects of user interface style within a learning environment. Future work includes more controlled experiments on the impact of the task, and the size of the buttons and mice, on the use of these interaction styles. Observations of separate field studies on OLM environments revealed that children preferred using the touch-pad to the mouse when given the choice. Future plans include investigating the differences in performances of the use of the two interaction styles when using touch-pads instead of mice. Finally, this study focussed on children aged 7 to 9 years, as it corresponds to the beginning of multiplication apprenticeship. We are also interested in investigating the use of such interaction styles by children of other age groups, particularly extending it to 9 to 13 year olds due to the difficulty in realizing pointing tasks already revealed by Inkpen [4]. We believe that the results of such studies will help designers of educational software, and more specifically OLM applications, decide upon which interaction style to use in order to help children learn, and use the systems.

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