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COGNITIVE FACTORS RELATED TO USER INVOLVEMENT WITH COMPUTERS AND THEIR EFFECTS UPON LEARNING FROM AN EDUCATIONAL COMPUTER GAME

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Abstract—Cognitive theories proposed to explain the high motivation to use, and deep involvement with computers, often found in schoolchildren suggest three main factors. They are: desire in the user to control the computer; the user responds to a perceived challenge from the computer; and the user wishes to explore the complexity of the computer software. The paper describes an experiment using a specifically developed piece of software to investigate these factors and to assess their effects on involvement with and consequent learning from an educational computer game. The program developed for the experiment was a simulation designed to teach children what to do in the case of a domestic fire. Different versions of the game were produced each providing or lacking one of the factors proposed to create involvement. The versions provided control by giving the user a choice of routes through the simulation, complexity in the form of colour graphics to engender curiosity and challenge in the form of a high score table. One hundred and fifty pairs of primary school children, matched for age and ability, played two of the six versions and compared them on questions designed to assess differences in involvement with the two versions. They also completed a questionnaire on fire safety knowledge before and after playing the first version. The children enjoyed using the simulation very much but did not show much diversity in their choice of routes through it. They appeared to follow two main plans, either to get everything right or to see what happened if they did something wrong. The results, automatically recorded by the computer during the experiment, showed that being in control of the program was most important in creating involvement with it. Introducing challenge and complexity separately did not increase involvement by any significant amount. However, the children became more deeply involved when the program contained both complexity and challenge. Increased involvement was found to result in increased learning from the simulation. Thus, all three cognitive factors were found to increase involvement with control being the most important in affecting learning since, if the users did not feel that they were in control of the program, they could not become involved with it. These results support the concept of active learning and it is proposed that, where the student is in control of the learning process, enhanced learning should occur.

INTRODUCTION

Previous work on involvement with an activity has concentrated on intrinsic motivation to perform the activity and has resulted in three separate suggestions for the cognitive factors responsible.

The first is complexity proposed by Berlyne[1] in his theory of exploratory behaviour which can be summarised in that the complexity of a stimulus generates perceptual curiosity in people or animals, this is a state of high arousal that can be relieved by specific exploration of the stimulus.

However, White[2] puts forward an alternative explanation for exploratory behaviour. He suggests a theory of competence motivation where the individual is challenged by an object or task and tries to effect his will over it. This is in accordance with Piaget[3] who states that the exploratory behaviour of a child towards an object is both focusing the child's attention upon an object and also directing its actions upon the object in an attempt to master it.

Bruner[4] notes the importance of intrinsic motivation for learning in his technology of teaching, and considers that the will to learn consists of both curiosity and the drive to achieve competence. These are produced, respectively, by the complexity and challenge of the task.

Malone[5–7] used both these concepts to explain the high motivation found in microcomputer users in his theory of intrinsically motivating instruction as provided by educational computer games. He considers that the challenge of a program is made up of a number of goals which may vary during the program. When computer games were assessed by American schoolchildren the presence of a clear goal produced the highest correlation with popularity. This was closely followed by whether the game kept a score which is another way of providing challenge. Malone also proposed that complexity in a computer game will arouse a sensory curiosity in the user to explore

the game. He found that audio effects and randomness in the game, both forms of complexity, were important for involvement with computer games.

However, Malone ignores a third cognitive factor, control, suggested by De Charms[8] as being responsible for intrinsic motivation. De Charms stated that man is motivated primarily by a desire to produce changes in his environment, that is to say, to control it. This is confirmed by Csikszentmihalyi[9] who considers the sense of control over the environment to be the most salient feature of involvement or the flow state. The relevance of control in motivating computer users is emphasised by Stonier[10] who states that the most important reason why the computer constitutes such a powerful pedagogical tool is that its interactivity gives children a sense of control. Control over the computer figures prominently in both Papert's[11] and Turkle's[12] studies of people interacting with computers.

The importance of involvement for learning has long been accepted. Snelbecker[13] reviewed most of the research on teacher effectiveness and found that improved learning occurs when the student is constructively involved in the learning process. In fact, in experiments with American students. Anderson[14] and Ozcelik[15] found positive correlations between level of involvement and gain in achievement.

To investigate involvement with computer games and how it is related to learning from the computer, an experiment was set up using an educational computer game which could be altered to provide or lack each suggested cognitive determinant of involvement.

The computer game chosen was an educational simulation based on previous research[16] and was designed to teach children what to do in case of a domestic fire. The simulation, called VESTA, is run by a package of interacting programs, written in BASIC for the BBC Micro B. VESTA operates by presenting the player with a short description of their current situation with a picture of what can be seen followed by a choice of actions to take. The scene then changes to one depicting the results of the chosen action with another menu of options. This continues until the player escapes or is unable to continue through injury. By being able to make decisions and see their effect, children see and learn what they should do in this situation.

METHOD

Six versions of VESTA were developed each lacking or providing control, challenge or complexity, these are shown in Table 1. The element of control was easily removed from the simulation by omitting the menus of options available to the user; on pressing the space bar to indicate they had finished reading the description the subjects were moved immediately on to another scene and its description. Two routes were fixed in this way, one indicating what the player should do and the other what they should not do. Sensory curiosity engendered by the complexity of the program was removed by presenting the simulation normally but without using colour graphics to illustrate the scenes. Challenge was provided in the form of a high score table presented at the end of the simulation, the running total being kept in a corner of the screen, points were given for correct moves and taken away for useless or dangerous moves.

It was decided not to use fixed routes with the version with scores, since this would mean that the score would also be fixed and so it would not provide a challenge.

The six versions of VESTA presented in pairs makes 15 possible combinations and, as the combinations need also to be presented in reverse order to allow for order effects, that makes 30 combinations in all. To ensure that any preference for or increase in learning from a version of VESTA would be independent of subjects' age and ability, the children were assigned so that each combination was seen by 10 children of the same mean age and learning and reading abilities.

Table 1. Cognitive factors present in the versions of VESTA

Version	Choice of routes (control)	Graphics (complexity)	High score table (challenge)
1	No	No	No
2	No	Yes	No
3	Yes	No	No
4	Yes	Yes	No
5	Yes	No	Yes
6	Yes	Yes	Yes

The subjects first completed a questionnaire on general knowledge about fires including what they should do on discovering a fire at home. They were then allowed, in pairs, two goes on VESTA. After this the children were given the same questionnaire to see whether they had learned from VESTA. The children were then allowed another attempt on a second version of VESTA. They were asked to compare the two versions using a ratio scale displayed on the computer to answer questions assessing involvement with each simulation.

The computer recorded the subjects' names, their routes through the simulation and their answers to the final questions comparing versions seen.

RESULTS AND DISCUSSION

Three hundred subjects from eight local first and middle schools completed the experiment. The subjects' ages ranged from 5 years 9 months to 12 years 3 months with a mean of 8 years 11 months; 54% were boys.

When allowed to choose, they took a wide variety of routes through the simulation though one or two were much more popular than the others. On their first go 50% chose to go outside on discovering the fire and wake the neighbours to phone for the fire brigade. On their second go, 50% immediately rescued the others in the house, went outside with them and then woke the neighbours to call the fire brigade. On their last go 42% chose this route which is the correct one. The subjects could be seen to follow only three strategies. The most popular one was to do everything correctly, the second was to find out what happened if a deliberate error was made and the third was not to do the same things a second time. Usually the second and third strategies only occurred once the correct route had been worked out indicating a desire for a greater degree of complexity in the form of novelty.

The change in subjects' answer to question 5 of the before and after questionnaire, on what to do on discovering a domestic fire, the correct answer to which is given in VESTA, is shown in Table 2.

To show the changes in the subjects' answers to question 5 more clearly, the numbers of subjects who performed better, the same or worse after using VESTA were cross-tabulated with the version seen, as shown in Table 3. There was a significant association between the change over use of the simulation in answers to question 5 and the version of VESTA seen ($\chi^2 = 29.4$, $P < 0.01$).

Thus, the results show a general trend of performance improving as each involving cognitive factor is included in the simulation. The greatest change in numbers of those doing better or the same occurs when control is added in the form of choice of route and a decrease in those doing worse occurs when complexity is added to control. Indeed, the effect of adding control upon learning was found to be significant in the presence and absence of complexity in the form of

Table 2. Improvement in test scores for each version of VESTA

Version	Mean improvement
1	0.12
2	0.52
3	0.67
4	0.98
5	1.12
6	1.20

Table 3. Performance of subjects on question 5 what to do on discovering a domestic fire, by version of VESTA seen

	No. of subjects who		
Version	Did worse	Same	Did better
1. Fixed route, no pictures	11	22	17
2. Fixed route + pictures	10	19	21
3. Choice, no pictures	8	12	30
4. Choice + pictures	3	13	34
5. Choice, no pictures, with score	3	12	35
6. Choice + pictures, with score	2	13	35

graphics. The contrast of versions 1 and 2 vs 3 and 4 has $\chi^2 = 13.6$, $P < 0.01$. Inspection of the data shows that the availability of pictures and scores enhances learning but not to statistically significant levels.

Further investigation of involvement of the subjects with VESTA used eight questions to compare the two versions of VESTA seen. These asked the subjects whether, compared with the first version, they liked the second version more, concentrated on it more, wanted it to be repeated more, wanted it to stop more, learned more from it, found it to be more exciting, more interesting and more difficult or less and by how much. The mean answers to the questions for both presentations for each version are shown in Fig. 1 where a positive value indicates that overall that version was liked more etc. when it was shown, and a negative value that it was liked etc. less.

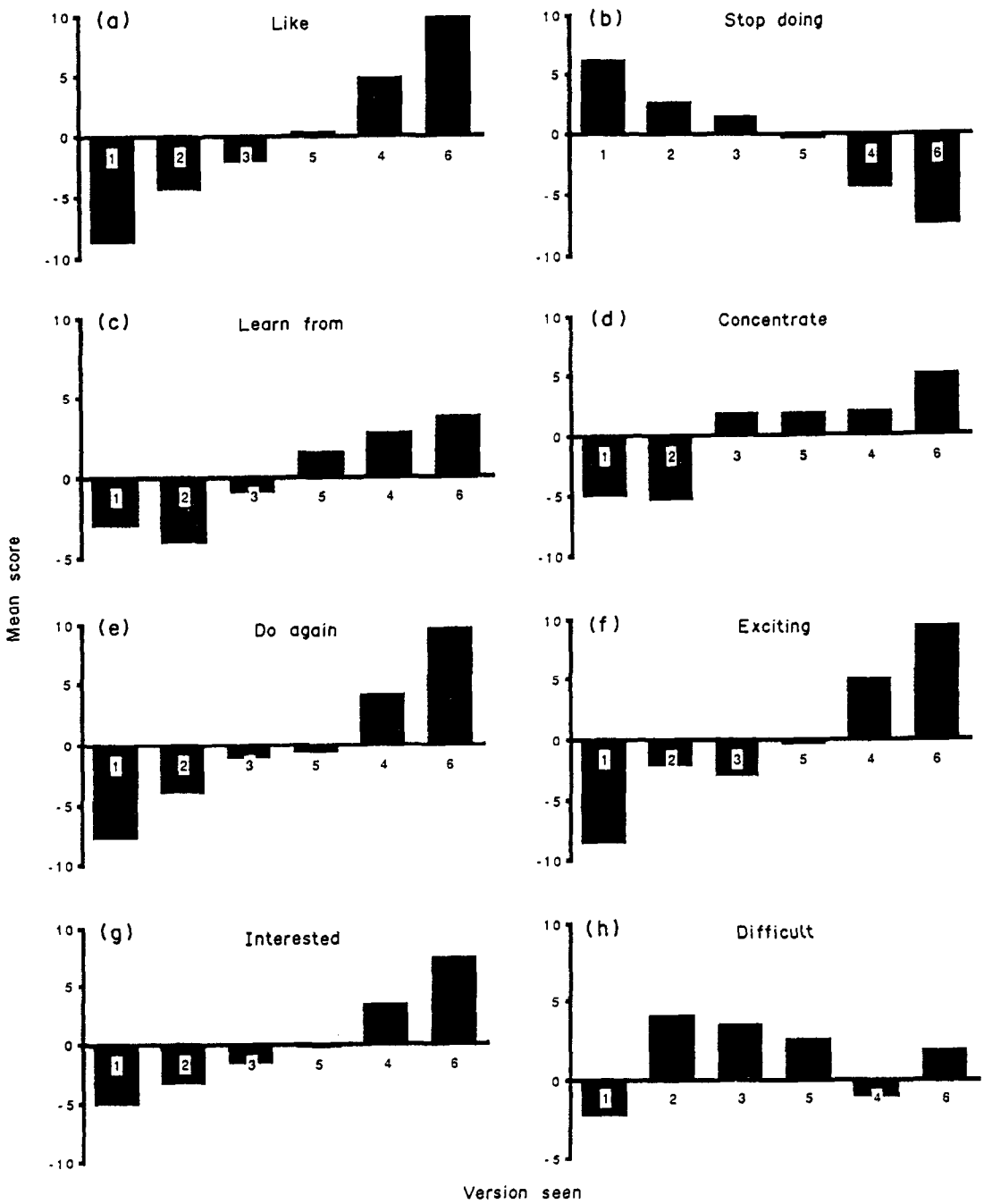

Fig. 1

The actual value indicates how much more or less. In the figure the order of versions 4 and 5 has been changed to demonstrate the trend in involvement.

The histograms in Fig. 1 show that they liked three versions of VESTA, control with complexity, with challenge and with both, considered they learnt more from them and did not want to stop doing them. They wanted to do the two versions, control with complexity and control with complexity and challenge, again and were interested in and excited by them. They concentrated only on the versions that they could control and more on the version with control and both challenge and complexity.

The subjects reported themselves as being more involved with version 4, control and complexity, than with version 5, control and challenge, but were shown earlier to have learnt more from version 5. They found version 5 more difficult and so felt they had not become involved with it however the increased learning shows the importance of challenge, through both target scores and an appropriate difficulty level.

Thus, being in control of the action is most important in learning from a computer simulation or game; players pay little attention if they have no choice to make, even less if they have no pictures to look at. The condition of no control but graphics is equivalent to an audiovisual presentation, an example of which has been shown to be inferior in transmitting fire safety knowledge to the normal version of VESTA[17]. Making the computer game more complex with the use of colour graphics to evoke curiosity in the user or adding a challenge in the form of a score to be beaten appear to have an equivalent effect on improvement of learning through increased involvement. Adding a combination of challenge and complexity was found to be most effective in generating involvement.

A final, interesting point suggested by the results of this experiment is that the failure of programmed learning machines was due to lack of involvement of the learners being taught. Skinner's theory[18] was that the learner was reinforced through operating the machine and getting the answers right. However, a programmed learning machine, like the versions of VESTA without choice, did not allow the user to choose the route to the next question and so did not provide true control. Also phrasing the questions so that the learner would nearly always get them right means there would be no challenge to enhance involvement.

CONCLUSION

The results of this experiment have shown that the amount of learning from an educational computer game may be significantly increased by giving the learner control over the action, and further enhanced by increasing the complexity of the game with colour graphics or providing challenge with a high score table. Animated graphics would further increase the complexity of the game but the designer should be careful not too make the game too complex for the intended user which would prevent them becoming involved. The inclusion of challenge in the form of scoring also enhances involvement of the user.

The apparent increase in involvement of the user with computer software found with the inclusion of graphics and scores replicates Malone's[5–7] results from which he developed his theory of intrinsically motivating instruction. However, this experiment shows his theory to be incomplete for it does not consider control or choice, the factor found here to be most significant in creating involvement with and learning from the software.

It can therefore be concluded that educational software would be much improved by allowing user control and providing a greater variety of challenge and complexity with less emphasis on reinforcement. Software where the user is in control is readily available and whose potential use in education could be better exploited.

It is suggested that educational programmers concentrate on providing illustrated simulations and games with varying challenges where the emphasis is on controlled exploration of a topic. However, use of such software ought still to be guided by a teacher to ensure that it is being used effectively.

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