AN ANIMATED AGENT AS A CHILD'S PARTNER IN PRACTICING OF COGNITIVE SKILLS IN A COMPUTER-MEDIATED ENVIRONMENT

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Master's thesis

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January 2000

JYVÄSKYLÄN YLIOPISTO
Psykologian laitos
HINTIKKA, SINI: An animated agent as a child's partner in practicing of cognitive skills in a computer-mediated environment

Pro gradu -tutkielma 39 sivua + 2 liitesivua
Ohjaaja: Heikki Lyytinen
Psykologia
Tammikuu 2000

ABSTRACT

This small-scale intervention study was conducted during the fall 1999 for examining the children's motivation to play a training program designed to acquire analogical reasoning skills. The training took place in a computer-mediated environment with an animated agent that applied in its behavior either the theory of cognitive tutoring and self-instruction or the theory of positive verbal reinforcement. Comparing the effects these two agents had on children's practicing the aim was to determine which factors enhance a child's motivation, and especially persistence, to practice analogical reasoning skills. In addition, the study was intended to shed light on the issue of learning effectiveness of the game program and the agents. The purpose was to find out if there were differences between the two agents in relation to motivation or pedagogical effectiveness.

The study was conducted in a public kindergarten in Jyväskylä. Four preschool children attended training period: two of them were boys and two were girls. Using alternating-treatment design, data was collected accross two experimental conditions (Condition A: the tutoring agent and Condition B: the verbally reinforcing agent).

The results suggested that the motivation to play a training program designed to practice analogical reasoning skills was determined more by individual factors than by the behavior model of the agent. Subjects varied in relation to persistence: one girl showed no decline in motivation after nine playsessions whereas the two boys used only two sessions. The pedagogical effectiveness of the game was demonstrated for two girls who used several play sessions, but not for the boys who played the game twice. In relation to pedagogical effectiveness there was no difference between the agents.

The results implied that the motivation of a child is determined by many factors, but the agent's behavior model as such seemed not to be among those factors. However, it is possible that these results were due to the implementation deficits in this particular program. The results also suggest that when designing appealing computer-mediated environments, individual variation has to be taken into account and create adaptivity and choice to the program.

Keywords: computer-mediated environment, training of cognitive skills, analogical reasoning skills, motivation, pedagogical effectiveness, an animated agent, tutoring, verbal reinforcement

CONTENTS

1. INTRODUCTION

Approximately 5-20 % of school-aged children suffer from mild developmental difficulties (Lyytinen, 1995). Usually these difficulties manifest in school as learning problems, for example as problems in math or attention or dyslexia. Unless additional individualized support is given, these kinds of disorders may become risks concerning later school career (eg., Ahonen & Aro, 1999). Computer-mediated environments have been proven to provide an effective and motivating way for training developmental difficulties; for example, in teaching children with various kinds of learning disabilities (Larsen, 1995); in practicing of speech perception disorders of language-learning impaired children (Tallal et al., 1996); and in remediation of reading and related phonological disabilities (Olson, Wise, Ring, & Johnson, 1997).

To be effective the training of impaired cognitive skills or neuropsychological processes requires extensive practice, which takes a lot of effort, time and persistence. For example, in the study of Tallal et al. (1996) the promising results of improving speech perception deficits with computer "games" were achieved through an intensive training period that involved daily training sessions for four weeks. The authors suggest that even greater benefits for speech perception deficits of language-learning impaired children may be expected to be achieved from earlier intervention as well as from a longer intervention training period.

An important question follows these notions: how can a child's motivation to practice cognitive skills in a computer-mediated environment be maintained? One answer to this question might be found in the field of educational technology, where there has recently emerged a number of attempts to create life-like pedagogical agents that could be enclosed in educational software (Lester & Stone, 1997; Rickel & Johnson, 1997).

The starting point for these efforts has been the assumption that the agents could enhance learning by assisting the learner in the tasks. But Lester et al. (1997) suggest that the pedagogical benefits of the agents may be even exceeded by motivational benefits. Their study revealed that animated pedagogical agents have a positive

impact on middle-school students. Students perceived the agents as being very helpful, credible, and entertaining. The authors speculate that there are two potential effects of agents on learning. First, the agents may have a direct cognitive effect by stimulating reflection and self-explanation. Second, the agents may significantly increase students' positive perception of learning experiences and that way they have potential to motivate students to interact more frequently and for longer periods of time with educational software. The authors suggest that studies which manipulate motivation levels (via payoffs or instructions) are needed for distinguishing between these two effects.

By taking various roles and following different behavior models animated life-like agents could enhance the motivation of children to persistent training of cognitive skills in a computer-mediated environment. Two possible roles of the agents were chosen for the present study: one of the agents applied in its behavior the theory of cognitive tutoring and the other one applied positive verbal reinforcement.

These two behavior models of the agents can be considered in the view of Larsen's (1995, p. 122) analysis of motivational factors in educational software. Three motivational factors mentioned by Larsen included a) "an interest based on unintegrated extrinsic rewards as found in many traditional drill-and-practice programs", b) "an interest based on integrated extrinsic reward systems as found in game-like scenarios", c) "the child's immediate intrinsic interest found in situations where the child is engaged in the task itself, and is not working in order to obtain extrinsic goals". These factors were applied to this study: A) The agents in this study followed the traditional logic of the computer games by providing material rewards after successful responses, this reward system functioned also as an instructional feedback system. In addition, the other agent offered positive verbal reinforcement by praising the learner. B) The agents inhabited a learning environment in which the tasks were placed in a game-like scenario. C) The other one of the agents was intended to call forth the child's engagement to the task and learning by giving corrective cues in the tasks. Theoretical considerations that formed the basis of the agents' behavior are discussed below separately for each agent, after which the research task of this study is presented.

1.1. An Agent that Applied Cognitive Tutoring

Larsen (1995) states that the feedback should include a "directional dimension" by providing corrective cues and information that show why the learner's action was wrong and how it can be changed. The tutoring this agent applied was constructed according to principles derived from Vygotskian theory of cognitive development.

Vygotsky's (1978) theory derives from the core assumption that cognitive functioning, such as thinking, reasoning, problem solving, or logical memory, occurs first on the social level and that the child then internalizes this in individual development. When applying this theory to practical problems in cognitive and educational psychology Vygotsky introduced the notion of 'the zone of proximal development' (Wertsch, 1984). Vygotsky defined it as *"the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers"* (1978, p. 86).

Vygotsky's concept of the ZPD leaves open the question of the nature of the guidance and collaboration that promotes development (Wertsch, 1984; Wood & Wood, 1996). He never specified or provided an account of what constitutes "problem solving under adult guidance or in collaboration with more capable peers". One attempt to answer the question of the nature of guidance is the concept of 'scaffolding', originally introduced by Wood, Bruner and Ross (1976). Scaffolding is a process wherein an adult provides support to a child learning to master a problem. Wood and Wood have specified the key tutoring functions of scaffolding: they involve *"recruitment of the child's interest in the task, establishing and maintaining an orientation towards task-relevant goals, highlighting critical features of the task that the child might overlook, demonstrating how to achieve goals and helping to control frustration"* (1996, p. 5).

The theory of cognitive tutoring - the concepts of the zone of proximal development and scaffolding - has been developed for human instructors. One caution should be noted when bringing up the computer for these considerations of instruction: the computer as a tool sets limitations to these theoretical considerations of in-

struction and tutoring. But there might also be a few advantages in using computers in instruction.

The main limitation in using a computer is related to a central theme in Vygotskian theory: to the interactional features of communication between the tutor and learner. Crook (1996) writes that computers cannot reproduce communicational at-that-moment richness that is characteristic to teacher-led instruction. A computer doesn't possess such flexibility as a human does: it is always possible that the learner invents unexpected novel ways to solve the problem and the computer-system classifies this innovation as a error (Wood & Wood, 1996). The computer can never replace a human as a an instructor but it can be a "...valuable niche in a broader context of instructional support", as Crook (1996, p. 98) says.

As advantages of the computer-based instruction could be mentioned the possibility to provide immediate feedback to learner's responses (Bradley, Welch, & Skilbeck, 1993; Wood & Wood, 1996). The negative feedback given after mistakes by a computer might be experienced less humiliating than the feedback given by a human instructor (Bradley, Welch, & Skilbeck, 1993). By computer it is comparatively easy to direct the learner's attention to the task by providing reminders of the learning goal and offer increasingly specific instruction as a child struggles (Wood & Wood, 1996).

1.2. An Agent that Applied Positive Verbal Reinforcement

The designers of traditional computer programs have utilized the behaviorists' assumption that any activity is more likely to occur if it is rewarded (Tennyson, 1995). The principle of reinforcement has been used by providing extrinsic material rewards to the player and these rewarding consequences have been used as incentives for learning (Kazdin, 1977). Recently in children's educational software agents have appeared that besides these material rewards offer positive verbal reinforcement after successful learning activity. Often these agents also perform some kind of funny animation that serves as a reinforcer. The behavior of the other agent followed the principles used in computer games by providing positive verbal reinforcement.

There has been an ongoing debate over the effectiveness of extrinsic rewards. There are studies suggesting negative treatment effects in educational and clinical settings (Koegel, Egel, & Williams, 1980) and decreases in creativity and intrinsic motivation after the introduction of rewards (eg., Amabile, 1986). On the other hand there are notions that providing of rewards can motivate a child to engage in various tasks (Eisenberger & Cameron, 1996) and that when rewards function as informative feedback they do not cause decreases in motivation (Ryan, Mims, & Koestner, 1983)

In traditional computer games the learning often consists of a trial-error - strategy - that is, the player has to discover the rules how to achieve the goal by himself and no instructions are given. Therefore, the goal is achieved through repetitive practicing. The principles of reinforcement and trial-error -learning are widely used in computer games that certainly are able to attract and engage children. Interesting questions follow this observation: Might the appeal of computer games be related to the notion that in these games you have to continuously and progressively excel yourself through repetitive practicing? Is the principle of reinforcement crucial in this excelling oneself?

1.3. The Research Task

The two agents were enclosed in a learning environment in which the task was to solve analogy problems (see Figure 1). This type of task was selected for two reasons. First, the analogical reasoning capabilities are needed throughout life for learning and especially in situations when novel information is confronted with reference to already known, familiar information (White & Manning, 1994). That makes the mechanisms and processes of analogical reasoning essential to cognitive development (Holyoak, 1984 in Alexander & Willson et al. 1987). Second, there has been intensive investigation of analogical reasoning, it's development and the training of analogical reasoning skills (Alexander, Willson et al. 1987; Goswami & Brown, 1989; Sternberg, 1977, 1979; White & Manning, 1994). This rich data base from the studies of analogical reasoning combined with the notion that children of kindergarten age are shown to

exhibit private speech during problem-solving tasks (White & Manning, 1994) provided a good basis for constructing tutoring for the other agent.

The purpose of this study was to find answers to the question of what kind of agent is a motivating and appealing partner for a child in persistent training of cognitive skills in a computer-mediated environment. In comparing the effects the two agents - the one that applies cognitive tutoring and the one that applies positive verbal reinforcement - had on preschool-children's practicing, the aim was to determine which factors enhance a child's *motivation* to practice analogical skills. The emphasis in studying motivation was on the aspect of persistence. More spesifically, the aim was to investigate if there were differences between the two agents in relation to children's persistence to play the game and to find out if the cognitive tutoring could bring forth the child's engagement to the task.

In addition, the study was intended to shed light on the issue of *learning effectiveness* with this kind of program enclosed with the animated agent. The purpose was to find out if children learn to solve analogy problems more effectively with either one of the agents. Especially, one interest concerned the effectiveness of cognitive tutoring models in solving the tasks. The question was if the computer-based tutoring performed by the agent could help children to solve analogy problems.

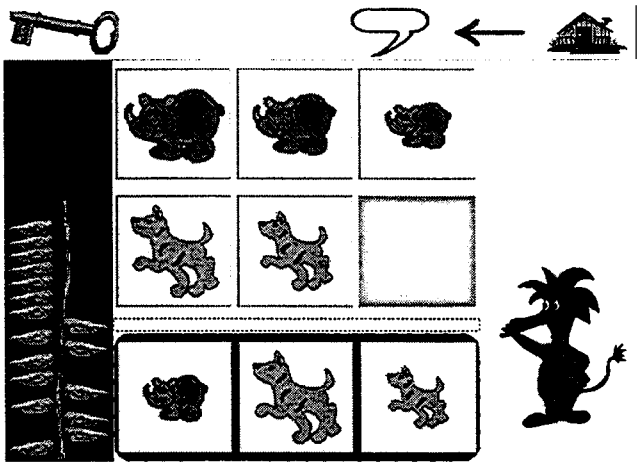

FIGURE 1. A picture of the game program illustrating one analogy problem and the animated agent.

2. METHOD

2.1. Subjects

Four typically developing preschool children from a public kindergarten in Jyväskylä were chosen as subjects in this study. Two of them were boys (S1, S2) and two were girls (S3, S4). Their ages ranged from 5 years to 5 years 1 month. Specific descriptions of the children are presented in Table 1.

The children were selected because of ther availability at research times and because of their age. Their ages were supposed to match with the difficulty level of the program and to the age during which analogical reasoning skills and private speech are developing (Alexander, Willson et al., 1987; Goswami & Brown, 1989).

TABLE 1.

Demographic Subject Information

Subject	Gender	Age
S1 (Valtteri)	M	5 years
S2 (Tomi)	M	5 years 1 month
S3 (Jenni)	F	5 years 1 month
S4 (Sonja)	F	5 years

2.2. Computer software and hardware

The computer software was specifically created for this study. The software was devloped in co-operation with the students of computer science at University of Jyväskylä

and it was written in C++ builder 3.0. The software included two structural parts: the game program which the animated agents inhabited and the part that kept record of the user's performance. The program ran Fujitsu Lifebook (B112), which is a small-sized notebook computer with a touchpanel.

2.2.1. The Game Program

At the beginning of the game program the animated agent introduced itself and the map of the route the child was able to proceed through by solving tasks. The route proceeded from home through a forest to a children's playhouse and these places were presented as the agent's living environment (see Figure 2). These three places served as three levels of the program and as the child proceeded from one level to the next one the tasks became more and more difficult. In order to get to the next level the child had to solve most of the exercises faced in the previous level.

At the beginning of the game, the agent told to child that at the final level (at the children's playhouse) there was a trunk with a treasure in it and by solving tasks the child was able to find it. On the left-side of the screen there was placed a tree that served as a reward system; every time the child's solution was right he/she got a new leaf to the tree and it grew. If the child hurried too much and interrupted the agent's speech he/she lost one leaf from the tree. When the tree was high enough the child was able to get a key to the trunk and found out the "secret" of the trunk. When this happened the trunk slowly opened and different kinds of toys and treasures rolled forward on the screen.

At home, at the forest and at the children's playhouse there were pictures of five items that were presented as "places" the child can visit. The child was able to choose the order of the places he/she wanted to visit. In each place there were two analogy problems. After the child had finished those two exercises he/she could choose another place to visit. The same kind of series of tasks was then introduced.

In analogy problems the child needed problem-solving skills. The analogy problem included two lines of pictures below each other (one example seen Figure 1).

In the lower row there was an empty place for one missing picture. A child was asked to press the picture among three options seen at the lower part of the screen that he/she thought was the missing one. In this task the child had to be able to understand the rule which determined the order of the pictures in the upper row, to see that the pictures in the lower row were placed according to the same rule and to draw conclusions what the missing picture might be by comparing these two rows.

What happened after the child's response to the task was dependent on two factors: the correctness of the response, and the experimental condition - that is, which one of the agents interacted with the child. Procedures after the response are described in the section of experimental conditions.

The program kept a detailed record of all the moves the child made while he/she was playing the game. The computer system monitored the child's success in solving tasks and adjusted the level of difficulty of subsequent exercises by regulating the access to the next level. If the performance was low the child had to practice tasks in the current level but if the performance was high enough he/she could proceed to the next level. At the third level (the children's playhouse) the tasks were divided to two difficulty "storages" so the computer was able to adjust also the difficulty degree within one level.

In designing the game program for the animated agents to function in, the aim was to utilize factors that have been found to be motivating in computer activities. According to Malone (1981) the dominant motivational factors in computer games include fantasy, curiosity and challenge. By creating an illusion of life of the agent and placing the tasks in the context presented as the agent's living environment, the child's imagination and *fantasy* were fostered. Two factors were designed to prompt *curiosity*: the placing of a trunk of treasures in the program and the introduction of different places for visiting. *Challenges* were offered to the child by constructing distinct difficulty-levels for the program. In addition to these factors, the growing tree was purposed to function as an *instructional feedback system*; by watching the tree the child was able to follow his/her process and to draw conclusions about the distance of the goal.

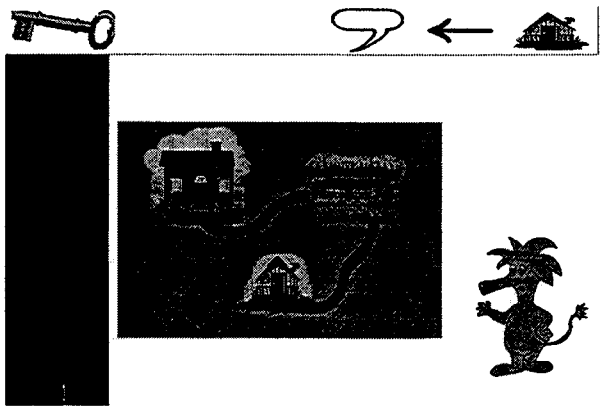

FIGURE 2. A picture illustrating the route the child had to proceed in the game.

2.2.2. The Animated Agents Enclosed in the Game Program

Throughout the learning session the children interacted with one of the two animated agents named Viki or Pietu. The two agents were identical in appearance and in vocal qualities. The agent's appearance and animations were designed by a graphic artist and the programmers rendered the animations on the game program. The agent remained onscreen, standing in the lower part of the screen, throughout the game session. Every now and then it exhibited several animations. For example, it performed a variety of explaining activities when the introduction of the route, the places, the tasks, and the tutoring took place. In case of wrong answers it showed displeasure and looked downcast. In addition, the other agent also offered reinforcement by expressing joy and congratulating the student when he/she gave right solutions.

2.3. Experimental Conditions

The behavior model of the agent (tutoring vs. verbal reinforcement) determined the experimental condition. That way two experimental conditions were used in the study. The differences between the two agents were exhibited after the child's response to the tasks. If the child's solution was *correct*, both agents gave a new leaf to the tree. What distinguished the agents was that after the correct solution the verbally reinforcing agent provided praise and congratulations to the child. The tutoring agent did not give any kind of response after the correct solution, the game simply moved on to a new task.

If the solution was *incorrect*, the tutoring agent provided instruction according to the two tutoring models described below and gave new opportunities to solve the task. The verbally reinforcing agent didn't give any kind of tutoring but offered two new opportunities. What was common for both agents was that the child didn't get punished for the incorrect answers but he/she was "punished" for hurrying too much. When the child was given new opportunities and he/she didn't listen to what the agent had to say, he/she lost one leaf from the tree.

2.3.1. Condition A: The Tutoring Agent

There were two kinds of tutoring models that occured during the game. If the child's first response to the analogy problem wasn't the right one, the first tutoring model occured. If the solution was still wrong after the first tutoring model, the agent offered tutoring according to the second tutoring model.

The first tutoring model was designed to be a general model that could be applied to every analogy problem. The idea in designing this first model was taken from the theory of cognitive behavioral approach and especially self-instructional training. There have emerged several attempts to create self-instruction statements. For example, the classic notions by Meichenbaum and Goodman (1971) include a) the defini-

tion of the problem, b) focused attention, c) self-reinforcement, d) self-evaluating coping, and e) error-correction skills and by Padawer et al. (1980) a) "find out what I am supposed to do", b) "consider all answers", c) "stop and think", d) "mark my answer", and d) "check my answer". These self-instructional statements were not used as such but the idea of stopping the child to think, and focusing his/her attention to the task was taken into account. The aim of the first tutoring model was to emphasize that in the analogy problem there was a rule that governed the order of the pictures. In order to discover that rule it would be essential to compare the pictures in the two rows. For example, the short comment spoken by the agent could be as follows: "*Stop. Compare the pictures in the upper row and in the lower row. Try to find out how they are similar.*"

The second tutoring model was a direct, task-specific comment spoken by the agent and it was developed to give additional instruction if the first model didn't help the child to find the solution to the problem. The idea of this model was derived from Sternberg's (1977) componential theory of analogical reasoning. According to Sternberg (1979) solving analogy consists of six processes, four of which are mandatory (encoding, inference, application, response) and two of which are optional (mapping, justification). In creating the second tutoring model we utilized five of Sternberg's processes: 1) *encoding* means that the subject perceives the term of the analogy and stores in working memory the relevant attributes and corresponding values. In our tutoring model this means that the objects and their attributes were explained to the child, 2) *inference* is the process where the subject discovers the relation between objects and stores that relation in working memory, 3) by *mapping* the subject names the perceived relationship between objects and discovers the analogy between the pictures in two rows, 4) in the process of *application* the subject compares the pictures in the lower row and the answer options and selects the right answer option, 5) when the subject has found the right picture he or she can finally give a *response*. These processes formed the basis for the agent's tutoring but were not applied directly to its utterances because analogy problems used in this study were somewhat different from Sternberg's analogy problems. The following example is an excerpt from our program (analogy problem seen in Figure 1): "*In the upper row you see at first a big rhinoceros, then a medium-sized and finally a small rhinoceros. In the lower row there are*

pictures of dogs and also these pictures are ordered by size. Compare these two rows and you'll find the answer."

2.3.2. Condition B: The Verbally Reinforcing Agent

The behavior of this agent represented principles of positive reinforcement. Besides offering extrinsic material rewards (a leaf to the tree) this agent provided social rewards to a child. The social rewards included all the positive gestures, animations and comments the agent displayed. After successful performance it offered verbal praise ("good", "excellent", etc.) and at the same time performed some animation (eg., jumping up and down). In the case of an incorrect answer, the agent gave two new opportunities similar to the procedure of the tutoring agent, but instead of offering instruction it just encouraged to try the task again.

2.4. Dependent Measures

A number of measures was used in an attempt to answer the problems presented in the research task. The *motivational effect* of the game was analysed through in the aspect of persistence and measured using time as the criterion. The number of the game sessions the child used and the amount of time the child spent playing the game in each session with either one of the agents were marked. After that calculations of the percentage as fractions of the amount of time each subject spent in playing the game program over maximum given time for playing were made. 100 % was rated when the subject played the game during the whole session (20 minutes) or until he/she reached the end of the game. The last mentioned criterion means that the session could last below 20 minutes if the subject reached the end of the game. In addition, qualitative analysis on the basis of observations was conducted for clarifying the motivational effect.

The *learning effectiveness* of the game program and the agents included performance ratings from each session - that is, calculations of the problems answered correctly. These numbers were estimated from each subject's individual records logged by the computer system. The effectiveness of the tutoring models was measured by counting the number of successful solutions after presenting the two tutoring models (the tutoring agent) and comparing that to the number of correct answers after merely offering new attempts (the verbally reinforcing agent). The motivational effect of the tutoring models was examined also by observing if the children listened to the tutoring or not.

2.5. Procedure and Setting

An alternating-treatment design was used in this study. This design was chosen because it permitted the comparison of the effectiveness of two experimental conditions but made it possible to avoid the requirements of stable baseline and stability in the data before introducing a new condition (Neuman & McCormick, 1995; Tawney & Gast, 1984). This design also minimized sequencing problems related to the order of the presentation of experimental conditions (Tawney & Gast, 1984). Moreover, qualitative analysis of the investigator's observations during play sessions was added to the data.

Each subject had daily game sessions that were allowed only for playing the game created for this study. Sessions were held in the afternoons when there was scheduled time for free play. The investigator offered the subjects an opportunity to come to play the game and the same investigator also accompanied the subjects during all sessions. Before the game could start the child was logged in by pressing his/her name on the screen. The session was over when the child wanted to finish the playing or when the game session was over (after 20 minutes or when the child had reached the end).

The two experimental conditions were alternated and counterbalanced session by session. Counterbalancing was done on different days, across subjects. Game ses-

sions were continued until the child was saturated (if the subject played below five minutes in two successive playsessions) *or* until the other experimental condition was demonstrated to be more effective *or* it was shown that neither condition was superior to the other.

All game sessions were conducted in a small room adjacent to the children's preschool classroom, at a time when all other children were in the classroom. That small room was typically used for children's playactivities. The room was furnished with a child-size chair and a table on which the computer was placed.

3. RESULTS

3.1. The Motivational Effect of the Game Program

3.1.1. Using Time as a Criterion for Motivation to Play the Game with the Agents

As Table 2 shows, there was variation in the motivational effect of the game between all subjects. In general, the results revealed that the girls in this study seemed to be more persistent in playing the game. The two girls received higher percentages of time spent in playing the game compared to the two boys. However, no general trend that would have reflected the motivational pattern of all subjects or distinguished the motivational effects of the two agents was found. The motivation to play the game seemed to be determined by individual factors.

In general, the differences between subjects in relation to motivational effect and persistence to play the game were quite large. The two boys who attended the study played the game only twice, whereas one girl (Sonja) showed no decline in motivation even after nine sessions. The motivation of the other girl (Jenni) was somewhere in the middle of these two extremes.

On the basis of the results in this study no difference between these two agents in relation to the motivational effect was found. Subjects preferred neither agent over the other; the minutes spent in playing the game were not determined by the agent. In addition, for the boys in this study the intervention period was too short for the differences to be expected to be revealed. The results of the motivational effect of the game and the agents and the subject's persistence are described below separately for each subject.

TABLE 2. The minutes each subject used playing the game and the percentage as fractions of the amount of time each subject spent in playing the game over maximum given time for playing. Below these numbers is stated which one of the agents was used in the session in question (Viki was the tutoring one and Pietu the reinforcing one) and what level the subject reached during that session. (E) means that the subject reached the end of the game and Exit is marked when the subject finished the program.

Subjects	**Sessions** 1	2	3	4	5	6	7	8	9
Valtteri	13 min 100% Viki (E)	17 min 100% Pietu (E)							
Tomi	20 min 100% Pietu III	16 min 100% Viki (E)							
Jenni	19 min 100% Pietu (E)	13 min 100% Viki (E)	14 min 100% Pietu (E)	13 min 100% Viki (E)	17 min 100% Pietu (E)	8 min 40% Viki (Exit)			
Sonja	20 min 100% Viki II	20 min 100% Pietu III	20 min 100% Viki III	20 min 100% Pietu III	20 min 100% Viki III	17 min 100% Pietu (E)	15 min 100% Viki (E)	12 min 100% Pietu (E)	15 min 100% Viki (E)

3.1.2. The Motivation Analysed Individually on the Basis of Time Spent in Playing and Combined with Observations During Play Sessions

Valtteri's motivational pattern. Valtteri's motivation to play the game was low (see Figure 3). He wanted to play the game only twice. After two sessions the opportunity to play the game was offered twice but he refused to use those opportunities. Valtteri's interest reflected no gradual decline in motivation; interest just suddenly fell down to minimum. When the last opportunity to play was provided he told that he and the other subject Tomi have decided not to play the game anymore because they didn't like to use the touchpanel and they didn't like the game because there were instructions in it. On the basis of two play sessions there was no difference between the two agents in relation to Valtteri's motivational pattern.

The observations during play sessions revealed that Valtteri was a quiet boy who knew how to play the game. He was hasty in his playing, wanting to proceed in the game as fast as he could. He didn't seem to stop to think what the answer might be, instead he seemed to use a trial-error strategy. He listened neither to the agent's speech nor to the tutoring models. The most important object for him seemed to be to get the trunk open, which he managed to do both times.

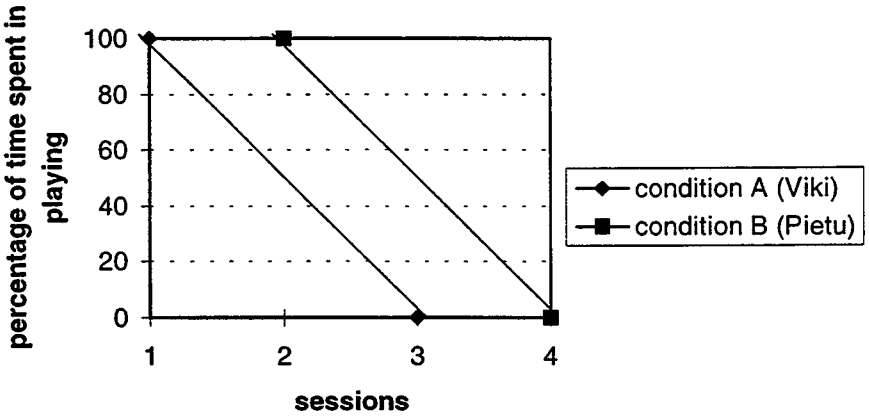

FIGURE 3. Figure illustrating Valtteri's motivation to play the game each time the opportunity was given.

Tomi's motivational pattern. Tomi's persistence to play the game followed Valtteri's motivational pattern: his motivation was quite low and after two sessions interest suddenly dropped to minumum (see Figure 4). As mentioned above, these two boys seemed to have some kind of common agreement of the game, which might have had an effect on their decisions to continue playing.

The order of the agents was counterbalanced between the subjects so that Tomi and Valtteri had opposite kinds of sequences. Tomi started with the verbally reinforcing agent and the second session was with the tutoring agent. However, no differences in relation to the motivational effects of these agents were seen during the two playsessions.

On the basis of observations, Tomi was a bit tense and quiet at the beginning of the study. In the middle of the first session he started talking about other matters unrelated to the game program. He played at a slower pace than Valtteri. Sometimes he stopped to think of the answer and listen to the tutoring models but sometimes he just proceeded forward quickly without listening to the speech. Occasionally, he seemed to be enjoying the game; he laughed at the tasks.

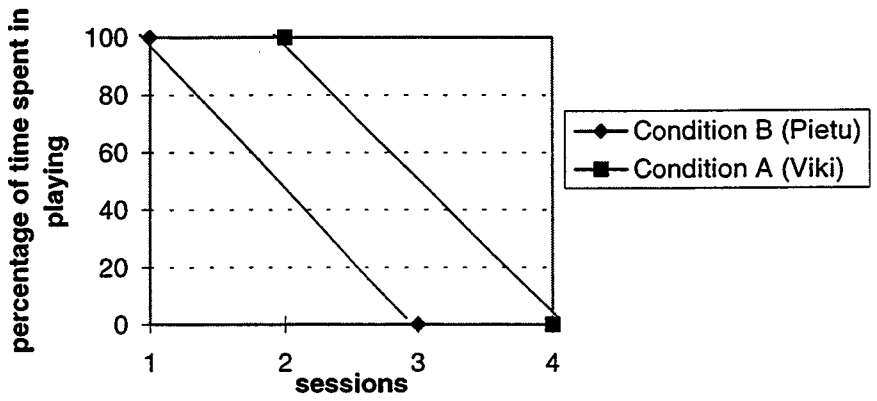

FIGURE 4. Figure illustrating Tomi's motivation to play the game each time the opportunity was given.

Jenni's motivational pattern. Jenni was motivated to play the game during five play sessions but at the sixth one she seemed to be tired of the game (see Figure 5). The sixth play session was a shorter one, Jenni played eight minutes (40 % of maximum play time) and after that she refused to play anymore. The interest seemed to decline in relation to the whole game, not in relation to either one of the agents. The shorter sixth session was with the tutoring agent, but because the verbally reinforcing agent started the intervention period it might be that the point of saturation just occurred during the session with the tutoring agent.

Observations during the sessions revealed that Jenni was quite shy and quiet at first. In addition, she was calm and played at a slow pace. Jenni looked forward to the investigator's approval when pondering the answers to the tasks and expected the investigator to give the right answer if she was unaware of it. At the beginning of the intervention her strategy to answer the problems was guessing. During the intervention her behavior changed. She started talking and making questions and comments, she interrupted the agent's speech and hurried in proceeding in the game. At the sixth session she was restless and wanted to talk about other unrelated things. She wanted to finish that session after eight minutes and said that she wants to play again on the following day, but when the opportunity to play was offered she refused.

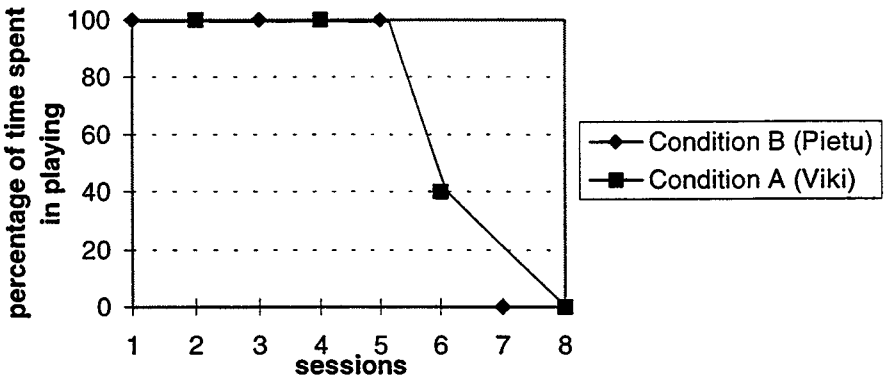

FIGURE 5. Figure illustrating Jenni's motivation to play the game each time the opportunity was given.

Sonja's motivational pattern. Sonja was the only subject who seemed to be really persistent in playing the game (see Figure 6). Her motivation remained at the level of 100% throughout the study. After nine sessions the intervention was finished although her motivation was still high; however, neither condition (the tutoring vs. the verbally reinforcing agent) demonstrated to be superior over the other.

Observations showed that at the first session Sofia was a bit confused of what the game was all about. She made a lot of comments and questions and didn't know what pictures she should press. She listened to the tutoring only occasionally. During later sessions she started to concentrate on the playing, taking it more slowly and listening to the agent. Still, occasionally she was restless during sessions and interested in other matters, such as the details of the computer. Her behavior varied during the sessions so that sometimes she was listening carefully to the agent and sometimes she just hurried on without paying attention to the agent. At the seventh session she disclosed that she had noticed the differences between the agents; she said that she likes the green one more (the tutoring agent). Although she said that, the percentage of time spent with either one of the agents during the following two play sessions was the same.

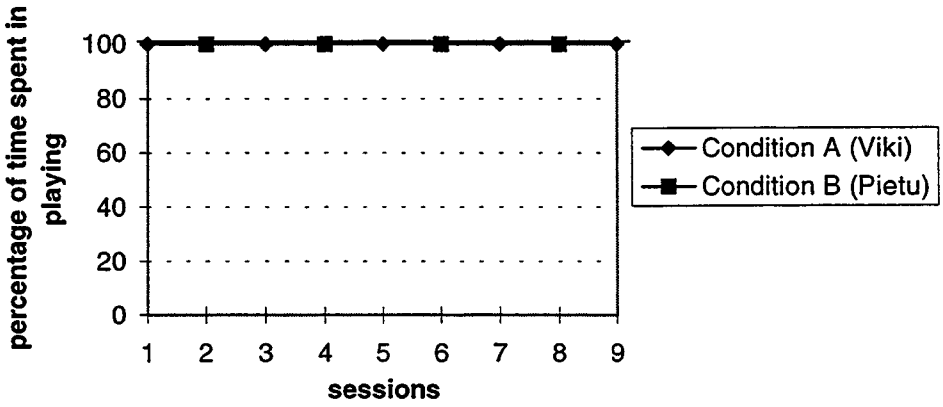

FIGURE 6. Figure illustrating Sonja's motivation to play the game each time the opportunity was given.

3.2. The Pedagogical Effectiveness of the Game Program and the Tutoring Models

3.2.1. The Performance Scores as Measures of Pedagogical Effectiveness of the Game Program

The pedagogical effectiveness of the game was measured as performance ratings that were calculated from each subject's logged files separately for each session and for each two new attempts to solve the task. Figure 7 shows subjects' percentages of problems answered correctly at the first attempt at each session. As the Figure illustrates, the subjects varied in the initial ability to solve analogy problems. The percentages of problems answered correctly at the first session ranged from 25 % to 64 %. Two of the subjects (Valtteri and Jenni) reached the end of the game at the first session.

The learning effectiveness of the game varied between the subjects. Since the two boys used only two sessions, not much can be said in respect to the learning effectiveness on their behalf. Valtteri reached the end both times he played the game, still there happened a decline in his performance between the two sessions (from 64% to 40%). The other boy in this study (Tomi) managed to proceed to the end only at the second session. The girls in this study had longer intervention periods and they had upward trends in their performances: Jenni received the highest percentage of all subjects during the final two play sessions and Sonja's scores were slowly increasing during the intervention.

The results of the differences between the agents in relation to pedagogical effectiveness were quite ambiguous. On the basis of the results no conclusions about the differences between the agents in relation to the pedagogical effectiveness can be drawn. One reason that makes the comparisons between the agents difficult is that the children had distinct patterns of listening to the tutoring, and some didn't listen to it at all. During the intervention period of Valtteri, as the agent changed from tutoring to the verbally reinforcing agent there occurred a slight decline in his performance but

otherwise there could be seen no differences between agents in promoting learning effectiveness.

The effectiveness of the tutoring models was analysed by comparing the performance scores between the agents - that is, the number of answers completed correctly after providing the tutoring or after merely offering a new attempt. The results of the pedagogical effectiveness of the agents and the tutoring models are analysed separately for each subject below in the following section. The tables showing the performance ratings of each subject are presented in Supplement 1.

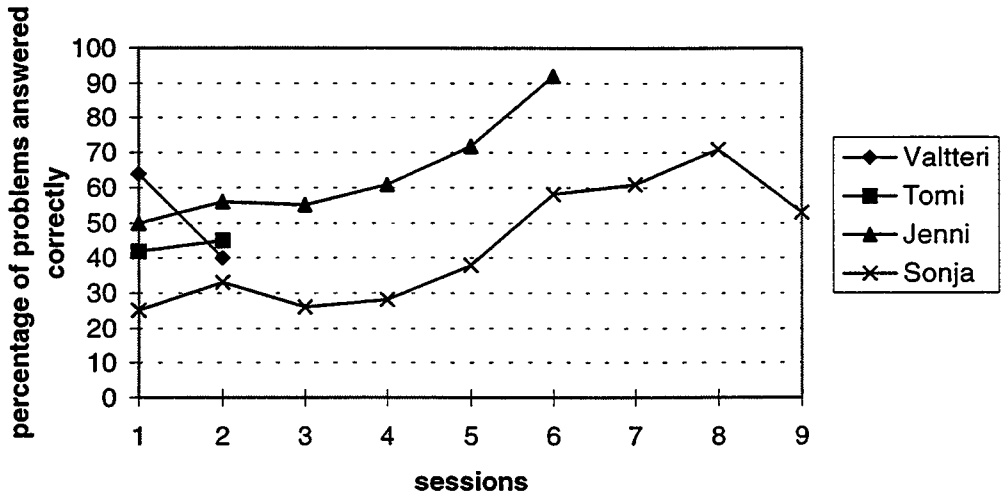

FIGURE 7. Performance of each subject calculated as the percentage of problems completed correctly at the first attempt without any tutoring or new attempt to solve the task.

3.2.2. The Pedagogical Effectiveness of the Game Program Analysed Separately for Each Subject

Valtteri's Performance. On the basis of two play sessions a complete analysis of the pedagogical effectiveness of the game for Valtteri is impossible to conduct. Valtteri seemed to have an initial ability to understand analogy problems (see Figure 8): at the first session Valtteri's performance exceeded other subjects' performance (64 % at the

first attempt, 81 % after the first tutoring model and 100 % after the third tutoring model). He managed to reach the end of the game both times he played the game.

An interesting decline in Valtteri's performance occured between the first and the second session. The agent changed between these sessions from the tutoring agent to the verbally reinforcing agent. However, on the basis of a single case the conclusions of the effect on the agent as a cause for decline has to be considered carefully. One discouraging piece of evidence for that comes from the fact that there was no preference in favor of the tutoring models at the first session compared to the mere offering of new attempts at the second session, which may be due to the observation that Valtteri listened to the tutoring only occasionally. He was more interested in proceeding in the game and maybe he felt that the tutoring would have slowed him down. The question of the effectiveness of the few heard tutoring models remains unclear.

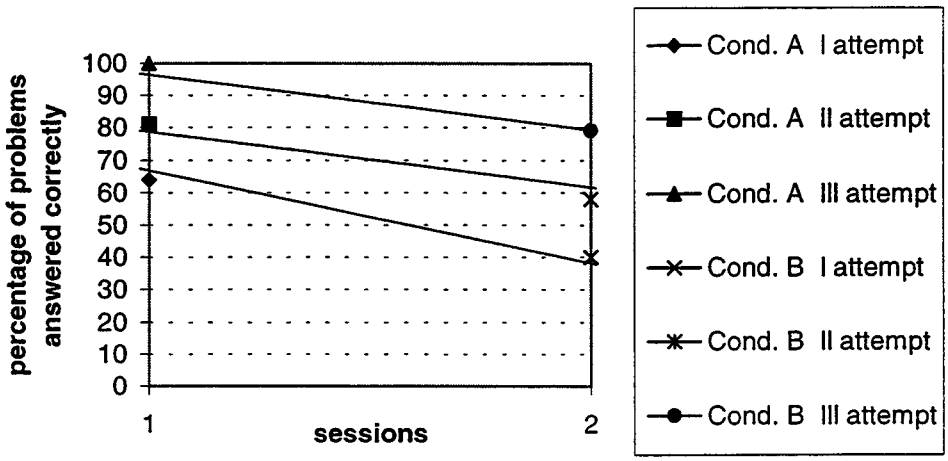

FIGURE 8. Figure illustrating the percentage of Valtteri's performance ratings during the two play sessions. The bottom line illustrates the performance at the first attempt, the line in the middle the performance at the second attempt (with the tutoring agent after the first tutoring model) and the upper one the performance at the third attempt (after the second tutoring model). Condition A included the tutoring agent and condition B the verbally reinforcing agent.

Tomi's Performance. At the first session Tomi's performance was lower than Valtteri's, but the scores of the second session exceeded Valtteri's scores of the second session (see Figure 9). Tomi's performance stayed roughly at the same level during the two play sessions, although a small increase did occur between these two sessions (at the first attempt from 42 % to 45 %). This small improvement in percentage was enough to get Tomi to the end of the game at the second session.

Tomi received better scores with the tutoring agent at his second play session. Unfortunately, the intervention period was too short in duration for any conclusions to be drawn about the pedagogical effectiveness of these two agents. When the performance ratings after the tutoring models were compared to ratings after mere new attempts, no differences were seen. The tutoring models did not seem to be effective or helpful in Tomi's performance.

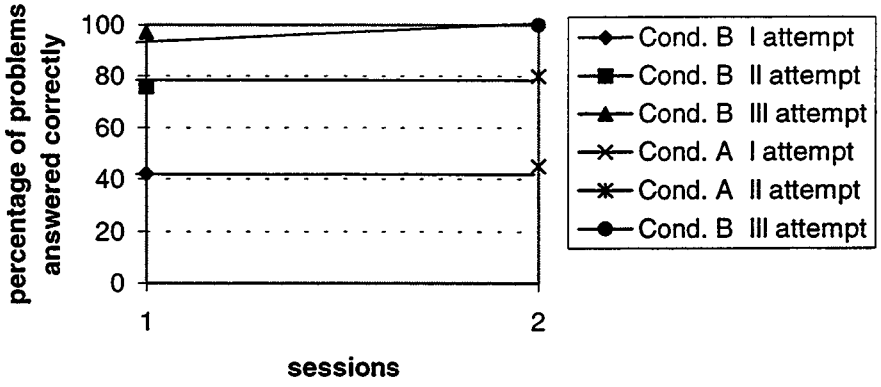

FIGURE 9. Figure illustrating the percentage of Tomi's performance ratings during the two play sessions. The bottom line illustrates the performance at the first attempt, the line in the middle the performance at the second attempt (with the tutoring agent after the first tutoring model) and the upper one the performance at the third attempt (after the second tutoring model). Condition A included the tutoring agent and condition B the verbally reinforcing agent.

Jenni's Performance. Jenni had an upward trend in her performance throughout the intervention period (see Figure10). At the beginning of the study her strategy seemed to be more of a trial-error strategy than real consideration on how to answer to the problems. However, she reached the end of the game in five play sessions; the sixth session was too short for reaching the final level. Jenni seemed to derive benefit from the game program: her scores increased gradually from 50 % to 92 % during the six sessions. Although the largest improvement in percentage occurred from the fifth session to the sixth session (from 72% to 92 %), the sixth one was so short in duration that the percentage can't be compared directly with other play sessions. The actual largest improvement seemed to happen between the forth and fifth sessions (from 61 % to 72 %).

The results showed no differences between the agents in relation to the pedagogical effectiveness. The performance increased throughout the intervention period, not in respect to either one of the agents.

The effectiveness of the tutoring models remained a little bit obscure, conclusions have to be drawn carefully for Jenni listened to the tutoring only occasionally. One interesting result in Jenni's performance was related to the percentages at the second attempt and to the question of effectiveness of the first tutoring model: the percentages at the second attempt increased from the forth session to the fifth session (from 74% to 89%). The fifth session was with the tutoring agent and after that session her performance in respect to second attempts kept going up. The conclusions drawn from this increase might be that the first tutoring model was effective in solving the tasks or that Jenni's strategy to solve problems was getting more effective. As she played the game she might have learned to choose the answer from two options close to each other and to exclude the clearly distinct one. Jenni's performance was almost 100 % at the third attempts (after the second tutoring model) in every session except one (third session was 97 %).

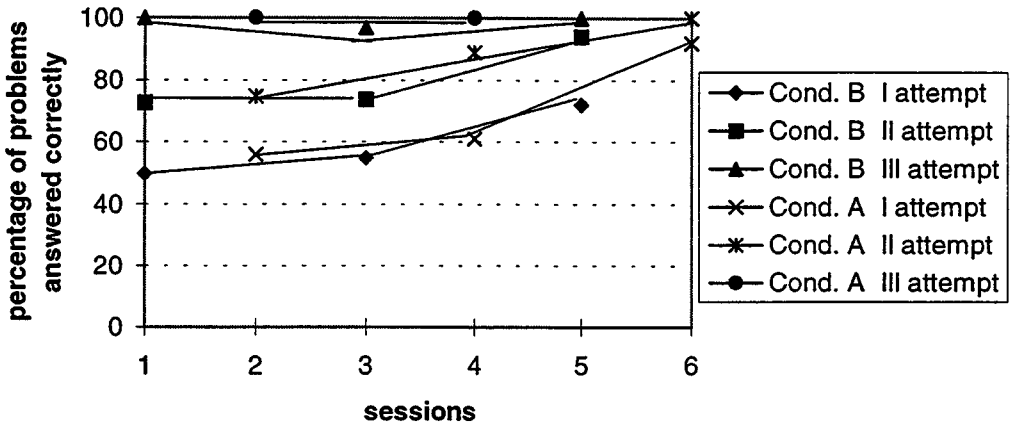

FIGURE 10. Figure illustrating the percentage of Jenni's performance ratings during the six play sessions. The bottom line illustrates the performance at the first attempt, the line in the middle the performance at the second attempt (with the tutoring agent after the first tutoring model) and the upper one the performance at the third attempt (after the second tutoring model). Condition A (the tutoring agent) and condition B (the verbally reinforcing agent) are illustrated with separate lines.

Sonja's Performance. Sonja's performance was the most interesting one of all subjects, since she had more sessions than any other subject, and her initial level in solving tasks was quite low (25 % at the first session). Sonja's performance was slowly and gradually improving during the intervention period, as Figure 11 show. The performance stayed roughly at the same level during the first four sessions, but started to improve at the fifth session. The percentages increased between the forth and eighth session from 28 % to 71 %. However, the question was whether Sonja was learning to solve the analogy problems or was she just remembering the right answers to particular tasks (there was, however, variation in the tasks so that the same task appeared only every third time). At the ninth session there occurred a decline in performance, the percentage descended to 53 %. This might be due to the fact that there was a few days break in the intervention because of Sonja's absence.

The results indicated no differences between the agents in performance at the first attempt (without any tutoring) but there were some small differences when it

came to providing new attempts to solve the tasks vs. offering the tutoring models. At the beginning of the study the first tutoring model did seem to be more effective than a mere new attempt, but at the sixth session it seemed that this difference was diminishing. The same result in a smaller scale applied to the second tutoring model: it seemed to provide a small benefit over a new attempt at the beginning of the intervention, but the evidence for that was too scarce for making reliable conclusions. An interesting result was that although the tasks could be solved by guessing (there were only three answer options and three attempts to solve the task), Sonja's performance attained 100 % only once, suggesting that she really had difficulties in understanding the tasks.

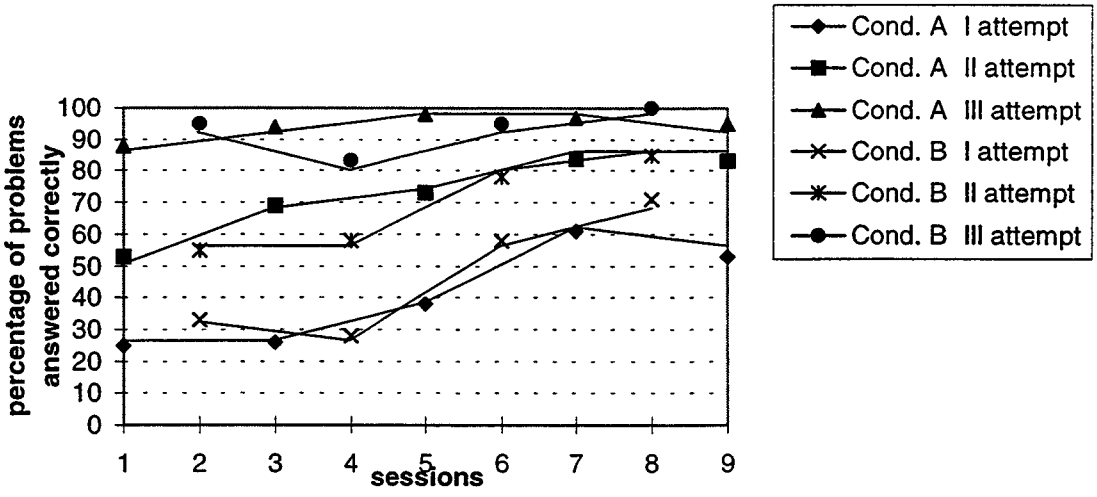

FIGURE 11. Figure illustrating the percentage of Sonja's performance ratings during the nine play sessions. The bottom line illustrates the performance at the first attempt, the line in the middle the performance at the second attempt (with the tutoring agent after the first tutoring model) and the upper one the performance at the third attempt (after the second tutoring model). Condition A (the tutoring agent) and condition B (the verbally reinforcing agent) are illustrated with separate lines.

3.3. Subjects' performance compared to their motivational pattern

The results of this study indicated that motivation to play the game seemed to be determined by individual factors. Malone's (1981) suggestion was that to be intrinsically motivating the computer game should offer challenge to a child. The question was if the persistence of the children in this study was related to the experienced difficulty level of the program.

The Figures 12,13, 14 and 15 illustrate the motivation of the children compared to their performance. On the basis of these results it seems that again subjects varied in respect to the relation between motivation and performance. No single point in percentage of performance was found that would have caused a decline in motivation for every subject. There was a clear difference between boys and girls: the motivation of the boys decreased to minimum when their percentages of performance ranged from 40% to 64%. Although the percentages remained relatively low it has to be kept in mind that both reached the end of the game. That way the challenge of the game may have diminished.

The girls had more a distinct pattern than the boys concerning the relation between performance and motivation. They wanted to continue playing longer than the boys, even when they had reached the end of the game a few times and the percentages of their performances exceeded the percentages of the boys. Jenni had a point of saturation during the sixth session when her percentage of performance was 92 % (the percentage of previous session was 72 %), and she had reached the end of the game five times. Sonja's motivation remained high even after her performance exceeded 71 %. When the intervention was finished for her, she had got the trunk open four times. The cause for this difference between the boys and girls is difficult to clarify on the basis of this study. There could have been some other factor than the game itself that caused the girls to use more play sessions than boys, even when their performances were approximately the same.

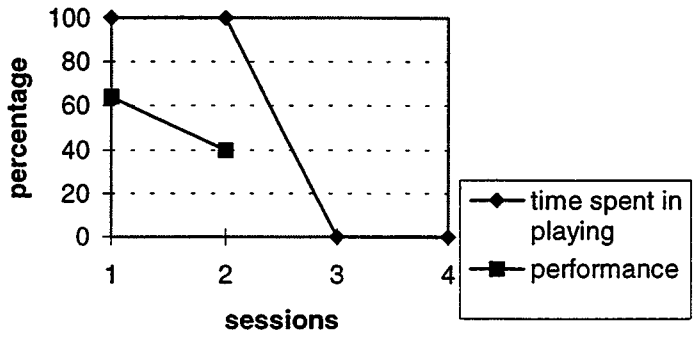

FIGURE 12. The relation between motivation and percentage of performance for Valtteri.

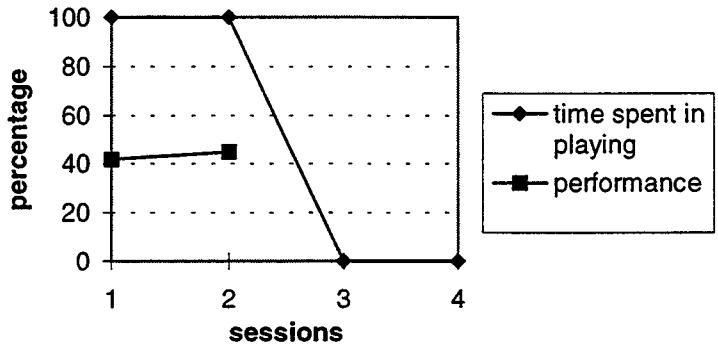

FIGURE 13. The relation between motivation and percentage of performance for Tomi.

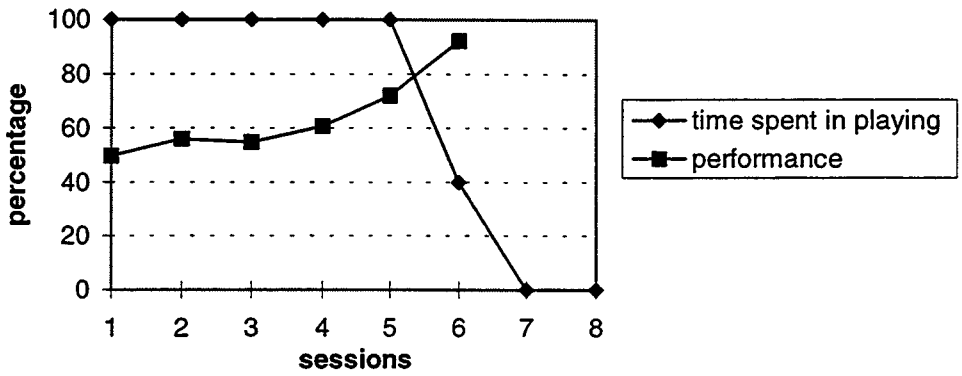

FIGURE 14. The relation between motivation and percentage of performance for Jenni.

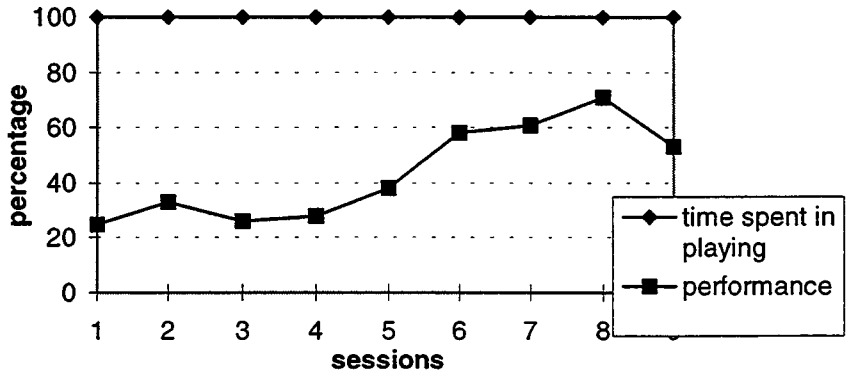

FIGURE 15. The relation between motivation and percentage of performance for Sonja.

DISCUSSION

This small-scale intervention study was conducted for examining children's motivation to play a training program designed to acquire analogical skills in a computer-mediated environment enclosed with the animated agent. More specifically, the aim was to find out if there were differences in motivational and pedagogical effects of the two agents with different behavior models: the other one was a tutoring agent and the other one applied positive verbal reinforcement. The results of this study demonstrate that no general differences between these agents were seen in relation to motivation or to learning effectiveness.

The motivational interests towards training seemed to be determined more by individual factors than by agents' behavior. On the basis of the results of this study no general trend was observed that would have reflected the motivational pattern of all subjects. The motivation of the two boys in this study dropped down to a minimum after two play sessions, whereas one girl wasn't tired of the game even after nine sessions. The motivation of the other girl was somewhere in between these two extremes: she used six play sessions. There seemed to be no gradual decline in the motivation of the subjects, instead there occurred a certain solitary point of saturation after which the subjects didn't want to play the game anymore. Differences emerged between the girls and boys of this study in relation to motivational patterns, which might in part be due to the fact that the designers were females. This verifies Greenfield's (1994) proposition for recruiting females to the designing of computer activities for getting the girls interested, also.

The motivation was compared in relation to the percentage of performance for examining if the difficulty level of the game was determining the child's motivation. There was some evidence suggesting the importance of challenge, confirming Malone's (1981) notion of intrinsically motivating factors in computer games. However, the boys and girls differed in respect to this relation of motivation and challenge: the girls continued the playing longer than the boys, even when their performances were at the same level and even exceeded the performance of the boys.

This study demonstrates that motivation is a tricky variable to measure. The research task of the motivational effect was focused on the aspect of persistence to play the game program and that is a reason why the time was used as a dependent measure. However, time as a criterion is quite a rough measure and it doesn't catch all the important aspects of motivation. For example, it fails to tell when the child is enthusiastic and enjoying his/her activity. Using subjects' own choice to come to play or not may reflect besides motivation also social compliance.

One important question of motivation remained unclarified in this study: the point of intrinsic vs. extrinsic motivation. It wasn't possible to examine the motivation more specifically and to analyze whether the subjects' motivation was more extrinsic than intrinsic. Intrinsic motivation is based on achieving meaningful personal goals that aim at learning rather than external rewards (Larsen, 1995). A more qualitative approach and systematic observations would have been needed to study motivation more thoroughly.

The learning effectiveness of the game was different for each subject. Not much can be said about the learning effectiveness for the two boys since they played the game only twice. The performance of the other boy remained at the same level, whereas the performance of the other boy dropped from 64 % to 40 % between the first and second session as the agent changed. His performance was lower with the verbally reinforcing agent. However, on the basis of a single case no general conclusions of the effect on the agent as a cause for decline can be drawn.

The girls' performance patterns suggest that analogical skills can be trained in a computer-mediated environment. Both girls had upward trends in their performances. Of special interest was the performance of the girl who used more sessions than any other subject. For her the intervention period was finished after nine sessions because neither condition (the tutoring vs. the verbally reinforcing agent) was superior over the other. She seemed to derive benefit from the whole intervention period; her performance measures increased from 25 % to 71 %. For the other girl the actual increase in performance was from 50 % to 72 %. Neither agent was observed to be superior over the other in pedagogical effectiveness for either girls.

The results of the effectiveness of the tutoring were quite ambiguous. The problem was that the children could bypass the tutoring if they wanted and children behaved diversely in relation to listening to the tutoring models. The intervention pe-

riods of the boys were too short for making any conclusions in respect to pedagogical effectiveness of tutoring. In the performances of the girls there were some minor differences between providing tutoring or mere new attempts in favor of tutoring. Especially for Sonja, at the beginning of the study the tutoring models did seem to be a bit more effective than mere new attempts but at the sixth session and after that this difference was diminishing. In general, the observations revealed that the children bypassed tutoring quite often so it seemed that they thought that the tutoring was ineffective. An other alternative explanation is that they just wanted to proceed in the game as fast as they could and the tutoring was slowing them down. This observation might reflect their previous experiences of computer games: usually the games are played at a fast pace and no instructions are given.

In summary, the results of this small-scale intervention study suggest that the *motivation* to play a training program designed to practice analogical skills was determined by individual factors. One of those individual factors may have been the experienced difficulty level of tasks: to be motivating the computer game or any pedagogical activity in general has to be challenging but not too difficult (Malone, 1981; Wood & Wood, 1994). In addition, the results may also imply that after the end of the game is reached and the target attained the motivation drops. The *pedagogical effectiveness* of the game was demonstrated for two subjects who used several play sessions, but not for the boys who played the game only twice.

The notion that no differences emerged between the agents in relation to the motivational or pedagogical effect remains unexplained. Could it be that the agents were too similar in their behavior models and appearance and the children couldn't distinguish them from each other? Anyhow, the tutoring agent wasn't entirely tutoring, since many reinforcing elements had been added to its behavior.

The tutoring mediated by the animated agent did not seem to be very effective and motivating as such. It is possible that the results were due to the implementation problems in this particular program (eg., the tutoring in this program was given only after wrong answers, which is not the best way to provide instruction) but they may also imply that computer-based instruction as such without any human contribution is hardly going to be effective and motivating. One issue became clear during the study: the theory of cognitive tutoring - the concepts of the zone of proximal development (Vygotsky, 1978), scaffolding (Wood, Bruner, & Ross, 1976) and self-instructional

training (Meichenbaum & Goodman, 1971) - is difficult to transfer to the computer. The technology has its limitations.

The computer-mediated environment for training analogical reasoning skills seemed to be motivating for one subject in this study. Sonja showed no decline in motivation after nine play sessions. However, nine sessions is not enough if the object is remediating developmental disorders. The aim of creating motivating environments for practicing cognitive skills is important, but there are many variables effecting the motivation of a child. On the basis of the results of this study the persistence to play is determined among others by social factors (eg., the adult's presence, working in pairs), previous computer experiences and the difficulty level of the tasks. The question for future research would be to analyse these factors and to keep in mind individual variation when creating computer-mediated remediation environments. In designing these environments an important factor would be to create adaptivity and to leave the right of choice to the program, also to the agents' behavior.

In general, the results verified the notion presented by Crook (1996) that computer-based training and tutoring are able to be effective for providing packaged exercises in circumscribed domains of knowledge. This is what computers are very good at. However, one should be alert not to reduce all instruction and domains of knowledge to this dense practicing of exemplary problems. The results of this study indicated that in motivating practice of cognitive skills, for thorough cognitive change to occur, there should be subtle social interaction that embeds the tutorial dialogue to more extensive contexts of shared learning experience.

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SUPPLEMENT 1.

The Tables 1, 2, 3, and 4 showing the performance ratings of each subject.

TABLE 1. Valtteri's performance ratings displayed separately at the first attempt, at the second attempt and at the third attempt. With the tutoring agent (Condition A) these attempts were given after the tutoring models. The percentages of new attempts are calculated as cumulative percentages.

Attempt	**Sessions** **1 (Condition A)**	 **2 (Condition B)**
1. attempt	23/36 (64 %)	19/48 (40 %)
2. attempt	+ 6 29/36 (81 %)	+ 9 28/48 (58 %)
3. attempt	+ 7 36/36 (100 %)	+ 10 38/48 (79 %)

TABLE 2. Tomi's performance ratings displayed separately at the first attempt, at the second attempt and at the third attempt. With the tutoring agent (Condition A) these attempts were given after the tutoring models. The percentages of new attempts are calculated as cumulative percentages.

Attempt	**Sessions** **1 (Pietu)**	 **2 (Viki)**
1. attempt	16/38 (42 %)	18/40 (45 %)
2. attempt	+ 13 29/38 (76 %)	+ 14 32/40 (80 %)
3. attempt	+ 8 37/38 (97 %)	+ 8 40/40 (100 %)

TABLE 3. Jenni's performance ratings displayed separately at the first attempt, at the second attempt and at the third attempt. With the tutoring agent (Condition A) these attempts were given after the tutoring models. The percentages of new attempts are calculated as cumulative percentages.

Attempt	**Sessions**					
	1 (Pietu)	**2 (Viki)**	**3 (Pietu)**	**4 (Viki)**	**5 (Pietu)**	**6 (Viki)**
1. attempt	20/40	20/36	21/38	22/36	23/32	12/13
	(50 %)	(56 %)	(55 %)	(61 %)	(72 %)	(92 %)
2. attempt	+ 9	+ 7	+ 7	+ 10	+ 7	+ 1
	29/40	27/36	28/38	32/36	30/32	13/13
	(73 %)	(75 %)	(74 %)	(89 %)	(94 %)	(100 %)
3. attempt	+ 11	+ 9	+ 9	+ 4	+ 2	
	40/40	36/36	37/38	36/36	32/32	
	(100 %)	(100 %)	(97 %)	(100 %)	(100 %)	

TABLE 4. Sonja's performance ratings displayed separately at the first attempt, at the second attempt and at the third attempt. With the tutoring agent (Condition A) these attempts were given after the tutoring models. The percentages of new attempts are calculated as cumulative percentages.

At-tempt	**Ses-sions**								
	1 (V)	**2 (P)**	**3 (V)**	**4 (P)**	**5 (V)**	**6 (P)**	**7 (V)**	**8 (P)**	**9 (V)**
1. at-tempt	8/32	14/42	9/35	11/40	15/40	23/40	23/38	24/34	21/40
	(25 %)	(33 %)	(26 %)	(28 %)	(38 %)	(58 %)	(61 %)	(71 %)	(53 %)
2. at-tempt	+9	+ 9	+ 15	+ 12	+ 14	+ 8	+9	+ 5	+ 12
	17/32	23/42	24/35	23/40	29/40	31/40	32/38	29/34	33/40
	(53 %)	(55 %)	(69 %)	(58 %)	(73 %)	(78 %)	(84 %)	(85 %)	(83 %)
3. at-tempt	+ 11	+ 17	+ 9	+ 10	+ 10	+ 7	+ 5	+ 5	+ 5
	28/32	40/42	33/35	33/40	39/40	38/40	37/38	34/34	38/40
	(88 %)	(95 %)	(94 %)	(83 %)	(98 %)	(95 %)	(97 %)	(100%)	(95 %)