Toddlers and Computers
www.samenslim.nl
Learning to learn through computer games: a fundamental approach

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Abstract — Educational computer games can benefit preschool children at risk of learning disabilities. Ineffective learning behaviour with, for example, poorly developed executive functions, may lead to such developmental disabilities as ADHD. An online educational game may help to improve ineffective learning and result in better learning strategies. The information on developmental progress produced by such games can benefit parents and teachers as well. The Dutch educational website *www.samenslim.nl* is aimed at stimulating effective learning behaviour in preschool children. To explore the effect of *samenslim* ('clever together') games on child development, we conducted two pilot studies. The first investigated the conditions that children have to meet in order to follow the game's instructions. Thirteen children were tested on the Mullen Early Learning Scale, which found that the children must have a developmental age of 35 months on the language comprehension subtest. The second pilot study analyzed the performance and development of seven children playing the *samenslim* game. Time series data present a detailed overview of the learning behaviour observed during the play sessions. The findings suggest that (1) learning behaviour can be adapted if children comprehend the instructions and (2) that development can be measured if all the factors involved are registered.

Index Terms — Educational computer games, ineffective and effective learning behaviour, learning to learn, preschool learning.

1 Introduction

Technology has become an essential part of our society. Computers have a strong influence on family life and in the Netherlands they are especially prevalent: 83% of the Dutch population own a computer, 78% own an internet connection and many households own more than one computer [1]. In contrast to other media such as television and film, a properly programmed computer opens up possibilities for social interaction. Instead of passive behaviour, which is the case when watching television, there is active involvement and concentration. The computer facilitates interaction: children can play on the computer with other children or adults.

Social interaction in the computer environment has a significantly positive impact on children's involvement in learning and their intrinsic motivation to learn [2]. Good motivation can enhance a child's learning experience. However, the interactivity of a computer program is not the only benefit to learning. Other positive effects include a program's ability to provoke and challenge children. It can also provide feedback by showing the direct effects of the children's actions.

Appropriate programs provide a good solution for children at risk of learning disabilities and for the parents and teachers of these children. Retarded early learning is a serious problem, as much for society as for the child. Developmental disability is particularly a risk among the children of immigrants, children of low social standing and children who already have developed or risk developing such disorders as ADHD or dyslexia. In most cases, learning problems do not come about through a lack of declarative knowledge (knowledge of facts), but are the result of inadequate learning behaviour [3].

Parents and teachers are naturally interested in their child's progress. Information on this is

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useful for gaining insight into the developmental status of their child. Better understanding ensures that parents can anticipate the needs of their children and stimulate them at the appropriate level. In the Netherlands, an online educational computer game has been created (*www.samenslim.nl*) in response to parental demand for objective information on progress in child development. *Samenslim* ('clever together') is not aimed at developing specific knowledge, but deals more with the development of effective learning strategies.

In order to judge the possible merits of this educational computer game, we first conducted a study of the literature on the effects of computer use in young children, including children with normal development as well as children in special education. The literature study also included the risk factors of learning, learning in a social context, and learning and educational games. Subsequently we carried out two pilot studies. The first identified the developmental age required by children in order to understand the instructions of the game. The second pilot study provided insight into the child's performance and measured its development whilst playing.

2 Learning, development and computer use by young children: a literature study

Children are starting to use computers at increasingly younger ages. As a result, there is a commensurate increase in interest in developing appropriate software especially for preschool children. An appropriate educational computer game can help prevent learning delays, especially in children at great risk of a learning disability. To our knowledge, almost no scientific research has been done on the positive and negative impact of computer use on preschool children (at risk). The results are often ambiguous and usually based on small-scale studies.

Online forums and educational magazines are full of discussions about computer use. Questions are posed on, for example, repetitive strain injury (RSI), internet privacy and safety, and the impact of computers on children and teenagers (e.g. the Dutch site *www.mijnkindonline.nl*).

2.1 Impact of computer use on several developmental fields

Preschool children familiar with computers show higher scores on tests measuring cognitive development than children who have not yet used a computer [4]. Subrahmanyam et al. [5] studied the impact of computer use at home on physical, cognitive and social development. Playing computer games at home improves the ability to read, visualize three-dimensional pictures and see several pictures at the same time. It appears that computer use relates to good performance at school. However, the research findings on social development were inconsistent.

Several studies [6–8] found learning effects in computer use. These include motivation, interest in a topic, self-esteem (particularly in complex and stressful tasks), thinking skills, social skills and motor skills, and also in the field of learning how to cooperate [9]. These studies investigated older children and adults and, for instance, how they used the internet for chatting, downloading music or playing games.

Small-scale studies [10, 11] of young children showed that there was lots of interaction between peers and between children and teachers. As we mentioned in the introduction, interaction seems to increase motivation and leads to a better learning experience [12]. Social interaction was defined differently in the various studies. One can draw the cautious conclusion that computer-controlled environments contribute to language development. However, this development occurs no faster than traditional language development methods [12].

2.2 Impact of computer use on children in special education

One study in England investigated teachers at seven schools for children with emotional and behavioural problems [13]. The teachers' perceptions were that information technology was effective for these children. It increased their motivation and improved their self-esteem. Information technology – being able to use a computer – increased the children's self-confidence and enhanced their social status and performance at school. According to the teachers, their concentration and attention span also improved.

Children in special education who were given computerized language training seemed to improve more in vocabulary and social skills

than children who were given only the standard curriculum. Children began repeating words heard while working on the computer. Those who had been unable to concentrate for long were subsequently able to interact longer with the computer. In four of the five toddlers taking part in the study, parental instruction seemed more effective than the help given by professionals [14]. Children with physical and emotional disorders became proud of their ability to use a keyboard. This success increased their self-esteem. Young children could follow the instructions easily when appropriate software was used [15].

2.3 Learning through educational games

A great variety of educational games for young children is available on the internet, for example on the Dutch website www.kinderpleinen.nl. Software developed for young children is often focused on promoting functional development (motor system, language, perception and cognition, and spatial insight functions). Practiced individually, these functions are viewed as preconditions for the skills that will be acquired later on at school, specifically with regard to reading and arithmetic. Repetition and play are central to acquiring knowledge and practising skills.

To our knowledge there are almost no scientific studies on the actual learning effects of specific educational games. Software developers often claim a game has a positive effect on a specific skill. Systematic research is needed to help parents and professional educators maximize the positive effects and minimize the negative ones. Dutch national policy is geared towards protecting children against negative effects of the internet, by focusing on aspects like the protection of privacy, RSI prevention and the SIRE advertising campaign against digital bullying [16].

2.4 Definition of learning

Learning means changing behaviour. Changes in behaviour can be more or less permanent, and can not be attributed to physical development (maturation), but to experience or exercise [17]. Learning is not just a cognitive process. Motivational, emotional and social aspects all play important roles in the process [18]. The learner's expectancies and the value attributed to the learning task are examples of these aspects. According to Reid [19] three kinds of knowledge are required in order to perform a task well:

1. Declarative knowledge: knowledge of facts, meanings of words and other data
2. Procedural knowledge: knowledge of how the activities should be carried out
3. Conditional knowledge: information about when and why certain activities have to be carried out.

Factual knowledge on its own is not enough to ensure that a task will be carried out well. It is also important to understand how and why the task should be carried out. Children at risk of learning disabilities often don't understand how and why a task should be done. A child is taught how to carry out a task correctly through parental instruction or feedback from the teacher.

2.5 Learning and social context

Learning is a fundamental process that takes place in a social context [18]. Interaction with other people is very important as it determines the way in which children regard certain phenomena. The social context of the child, playing for example in a group or with a sibling, can present new information that may be inconsistent with the learner's existing knowledge structures. This is how the learner adapts his or her existing knowledge structures and constructs new structures. Practising specific skills out of context – in terms of both meaning and social context – is not an effective means of promoting development as learning is bound to context. It enables children to learn how and when they can use their knowledge.

Vygotsky suggests that the interactions between a child, other children and educators are the source of the next developmental step [20]. The *zone of proximal development* states that activities that a young child cannot do independently or individually will succeed if this child receives help from a more capable person.

2.6 Effective and ineffective learning behaviour

Some children are at risk of developmental problems, for example immigrant children from low social standing or economic status and children with such developmental disorders as ADHD. Some risk factors for learning delays, including poorly developed executive functions (e.g. working memory, cognitive flexibility and inhibition control), are

specifically related to conditions like ADHD and criminality. Children from low income households often have poorly developed executive functions and fall behind at school [21, 22]. Marks [23] mentions such factors as lack of initiative, lack of participation or perseverance and refusal to try new things. Lack of initiative is one of the first consequences of acquired helplessness.

Problems cause concern as they extend to every domain of learning. Children must feel safe and be able to understand a task before they can be expected to start on it by themselves. Children with acquired helplessness show little perseverance and motivation during a task. Children who fail more often than succeed become increasingly less motivated to try because their actions in the past yielded poor results. Possibly they fail to choose the right answers because they don't understand that their behaviour has an influence on the results.

The literature presumes that it can be difficult for impulsive children to settle down to learning because they can't focus their attention on what they must learn. Because of their attention deficits, these children find it difficult to take in the full instruction and consequently may experience failure. The excessive verbal and motor activities of impulsive children leads to their making many mistakes and because of this, they often acquire feelings of helplessness and sometimes develop low self-esteem [24].

It is important to change inadequate learning behaviour into effective learning behaviour in family contexts and during preschool education to prevent interruptions and delays in the learning process. Diamond et al. [25] predict that improving the executive functions of preschool children can lead to lower demands for special education and a decrease in the number of children with ADHD-like disorders of the executive functions.

2.7 Educational games and inadequate learning behaviour

An (online) educational game can help change inadequate learning behaviour and teach a child the correct learning strategy. The child is able to acquire the correct learning strategy if it is given clear feedback by the game itself as well as guidance by parents who themselves can be guided by teachers giving them objective information about their child's learning progress. Learning to learn software may work well for children with ineffective learning behaviour. Using it may help them develop adequate learning strategies and thereby reduce their risk of acquiring a developmental disability.

Learning happens in a social context. Learning to learn should not only be focused on increasing knowledge and skills in traditional functions, but also on knowledge-recruiting strategies and on the development of executive functions. Strategic management of knowledge and information is of great concern in child development. It involves managing such aspects as goal-oriented learning, handling problems in the correct way, suiting the knowledge to the child, learning about one's own learning activities and teaching in a way that best suits the child. Parents play an important role in this and when given information on their child's learning-to-learn progress they can adapt their activities better to what the child already knows.

2.8 *Samenslim.nl* as an effective learning environment

The Edict Foundation (Education through Information and Communication Technology) has supported the creation of a Dutch-language educational game website: *www.samenslim.nl*. The goal of the platform is to develop effective learning behaviour in preschool children. The game automatically registers the children's mouse use which means that the children's level of knowledge and development of skills can be continuously measured. The data collected for scientific research can also be used to measure and optimize the effectiveness of the platform. The ultimate goal of the platform is to provide objective feedback to parents or professional educators on how the child in question is learning to learn. Parents need a good understanding of the learning behaviour of their children. When parents have this knowledge, they become more capable of anticipating the developmental level and needs of their children.

The goal of *www.samenslim.nl* is to stimulate effective learning behaviour. This concept is based on the idea that preschool children can be stimulated to discover learning processes and strategic behaviour through didactically justified computer games. Using this approach, learning behaviour and performance will be improved.

Fig. I. A screenshot of the hide-and-seek-game on *www.samenslim.nl*

In the *samenslim* game of hide and seek, two children play the leads: 'Sim' and 'Sanne'. The toddler playing the game is supposed to help Sim to find Sanne by clicking on objects behind which Sanne could be hiding. If the toddler clicks on a wrong object, only shifts the mouse or does nothing at all with the mouse, he or she is given helpful pointers from a friendly little bear, the toddler's playmate.

The game consists of five levels and each level has nine games in three different settings (park, farm and living room). A decision model, based on set decision rules, was made for research purposes to determine whether a child can progress to a higher level or has to go back to a lower level. Every child starts at the lowest level (one) and depending on how well he or she plays, reaches the highest level (five) sooner or later. Each level consists of a different concept level: increasingly complex objects on which the child has to click and a rising number of thinking steps.

Table II
Structure of the *samenslim* games

Locations	Levels					Total
	1	2	3	4	5	
Park	3	3	3	3	3	15
Farm	3	3	3	3	3	15
Living room	3	3	3	3	3	15
Total	9	9	9	9	9	45

Win or lose (played correctly or incorrectly), each game ends with a reinforcement procedure: a dance party with lively music so that the toddler can jump about and interact with the computer or a supervisor.

2.9 Research questions

The Department of Psychology at the University of Groningen is studying the measurement of learning behaviour of toddlers. The main research questions are: (1) Can learning behaviour be measured? (2) Does *samenslim* enable the attainment of relevant learning and developmental goals, namely effective learning behaviour? To answer these questions, we investigated the types of learning behaviour that take place while children play *samenslim*.

Ineffective learning behaviour can only change if children are capable of understanding and following the necessary instructions. Preliminary research is therefore required to identify the conditions which children must be capable of meeting in order to take part in the study. Only when this preliminary work was done could the actual research follow, to acquire detailed insight into the learning behaviour of the children playing *samenslim.*

This paper reports on two pilot studies based on the *samenslim* hide-and-seek game. The first was carried out to acquire insight into the conditions the children have to meet in order to play the game properly. The second pilot study observed the learning behaviour of seven toddlers playing *samenslim* to acquire a detailed overview of their individual development. With close observation of behaviour, it is possible to analyze the coherence between the different variables of one game-playing session. These observations can provide possible explanations for the course taken in some of the computer sessions.

3 Learning, development and computer use by young children: a literature study

3.1 Method

Just over half of the 13 children participating in the pilot study (children 1 to 7) came from a multicultural kindergarten in Groningen which has one class of seven toddlers aged from two to three years. The kindergarten was chosen because it was available and selecting it had no detrimental impact on the representativeness of the cohort.

Table III

Description of participating children

Child	*Gender*	*Calendar age (months)*	*Dutch background*
1	M	39	no
2	M	37	no
3	M	36	no
4	M	43	no
5	F	40	yes
6	M	46	yes
7	M	39	yes
8	F	34	yes
9	M	35	yes
10	M	54	yes
11	F	45	yes
12	M	29	yes
13	M	57	yes

The remaining six children in the study (children 8 to 13) were recruited to the *samenslim* study through a project which is testing children on the Mullen Scales of Early Learning: AGS edition. These tests are part of an ongoing psychometric project being conducted by the University of Groningen. Researchers are currently converting and validating the Dutch scores to Dutch norms. Raw scores per subscale are translated into developmental ages. In recent months, ten sets of parents have been asked if their children aged between two-and-a-half and five years could participate in the study. To date, six parents have contributed to the *samenslim* study.

The Mullen Scales of Early Learning (MSEL) is an American developmental test for children from 0–68 months old. The test consists of five subtests: gross motor skills, fine motor skills, visual reception, language comprehension and language production. The *samenslim* study employed four subtests: fine motor skills, visual reception, language comprehension and language production. The first author tested the kindergarten children (1–7) on the MSEL. The others (children 8–13) were tested by various students from the Department of Orthopedagogy observed by the first author. The children played the hide-and-seek games on *www.samenslim.nl*.

The seven children from the multicultural kindergarten played the *samenslim* games in a room close to their own classroom. The first author supervised these sessions. Children were randomly selected, and everyone in the class was given a turn at playing the games. If a selected toddler was not present, then testing took place the next time he or she was in the kindergarten. During the *samenslim* sessions, the remaining children were allowed to move around or play with each other in the classroom. All seven children took the MSEL tests separately in a quiet room.

3.2 Results

The duration and frequency of the computer sessions differed per child. For example, one toddler played through all the levels in one session lasting just 20 minutes. Another toddler needed three sessions of different lengths and in the final session four attempts at playing the highest level. The differences in duration depended on several factors. The session ended if a toddler said he no longer wanted to play. It also ended if the supervisor noticed that the toddler was no longer motivated or concentrating. Another reason for ending a session was if the toddler had to take part in kindergarten activities, for example the ‘fruit break’. The time between session one and session two varied per toddler, sometimes between two days to a week, depending on which toddler was available and on the duration of the sessions. All toddlers played the game in the same period. All toddlers were tested on the MSEL in the same week as the final *samenslim* session.
Table IV presents the scores of the Mullen Scales of Early Learning subtests. The raw scores of the subtests have been converted to developmental ages according to USA norms.

Table IV
Developmental age based on subtests scores on the Mullen Scales of Early Learning

Child	*CA*	*VR*	*LC*	*LP*	*FM*	*FIS*
1	39	45	29	30	34	no
2	37	61	34	31	40	no
3	36	46	25	34	37	no
4	43	52	36	40	48	yes
5	40	46	36	37	36	yes
6	46	52	46	45	40	yes
7	39	42	30	27	34	no
8	34	37	29	33	37	yes
9	35	40	37	36	33	yes
10	54	55	49	52	39	yes
11	45	58	58	68	55	yes
12	29	49	37	31	40	yes
13	57	64	61	67	67	yes

CA = Calendar age in months
Developmental age in months scored on four subtests:
VR = visual reception
LC = language comprehension
LP = language production
FM = fine motor skills
FIS = follows instructions for samenslim.nl

The relation between ‘language comprehension’ (LC) and ‘follows instructions for *samenslim*’ (FIS) is relatively high (r = .59). Therefore LC is a relatively good predictor of the success of the game player. It is almost impossible for a child to comprehend the

instructions of the *samenslim* game or the meaning of the game if he has an LC developmental age under 35 months. This is observable in both table IV and figure III.

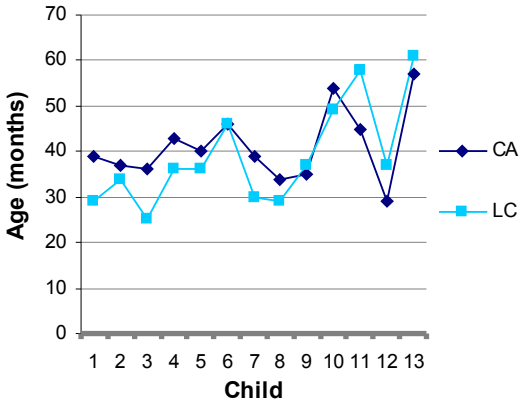

Fig.V. Language comprehension (LC) relative to calendar age (CA)

The LC score indicates how well a child understands the game instructions and applies to almost all the children in this preliminary study. The youngest child (12) with a low calendar age and a high language comprehension followed the instructions remarkably well. His score is very high for his age and that gives him a big lead over his peers. His visual reception scores are as high as those of the older children tested. His level of development gives him advantages in several fields (language comprehension, visual reception and fine motor skills) that allow him to understand the game at his age. Ineffective learning behaviour cannot be adapted if a child cannot comprehend the game instructions.

3.3 Discussion

The goal of *samenslim.nl* is to provide objective information about learning behaviour and child development. To provide this information, we need to analyze and measure learning behaviour. Development can only occur if the toddlers meet the necessary conditions. The Mullen Scales of Early Learning was used to investigate at which developmental age toddlers can understand the instructions for the *samenslim* game. It appears that language comprehension is the best predictor of a child's ability to understand the instructions. It is important to note that this was a small-scale study so this conclusion must be taken carefully.

Developmental age is not the only factor important to understanding instructions. This preliminary study did not take into account several other factors, for example the child's hearing capacity (auditory reception) and ability to distinguishing colours or objects, object permanence or the development of the tactile system. The child also needs to know how to use a computer mouse. The concept of cause and effect must be sufficiently developed so the child knows that moving the mouse will make the cursor move on the computer screen.

4 Pilot study II: which learning behaviour occurs while playing samenslim?

4.1 Method

Molendrift BV, an institute in Groningen devoted to orthopedagogical support, has conducted previous research into children's interactive game-playing behaviour, including their mouse use. Molendrift BV made video recordings of three girls and four boys playing *samenslim* games and this material was used for the *samenslim* study by the University of Groningen. All seven toddlers attended the same kindergarten, but came from different social backgrounds. Their ages varied from 29 to 53 months.

Using the video recordings from Molendrift BV, we observed the behaviour of seven toddlers with a video coding program (VidCodePro, IDP 2005) developed by the Psychology Instrumentation Service in Groningen. The program makes it easy to digitally encode behaviour observed in the videos. When behaviour is coded, it can be scored and analyzed per millisecond. The behaviour codes can also be converted for Excel, which enables data analysis in arbitrarily small time resolutions. The coding program helps to acquire a clear overview of behaviour at specific points in time. With the help of Excel macros and the Tablecurve2D 5.0 program, the time series were smoothed using the Savitsky-Golay filter method. This curve smoothing technique gives a good overview of behaviour and, as it averages the data dynamically over all the observations, it makes the data easier to interpret.

Seven videos were studied to investigate which variables possibly related to learning behaviour came to the fore during the *samenslim* game. These observations identified the following: emotions; concentration; on-task and off-task behaviour; non-verbal and verbal interaction with the computer or the supervisor; and asking for

and receiving help from the supervisor. We formulated a coding system based on these variables, assigning codes to all visible behaviours. We defined two kinds of behaviour: discontinuous (receiving help) and continuous (concentration) and formulated scales depicting intensity (concentration) and positivity/negativity (emotion). For example, 'strong concentration' was coded '4', 'moderate concentration' was coded '2' and 'weak concentration' was coded '1'.

4.2 Results

The inter-rater reliability of the behaviour codes were all >0.8. According to Monte Carlo analysis, which takes into account random variables and random similarities, it is highly unlikely that the observed inter-rater correspondence is due to chance alone. The goal of these observations was to make time series of the learning behaviour of individual children during *samenslim* play sessions. The resulting overviews were then used to analyze the coherence of the variables.

Figure VI illustrates the observed time series for one toddler. The curve-smoothing technique reduces fluctuations, thus enabling better data interpretation.

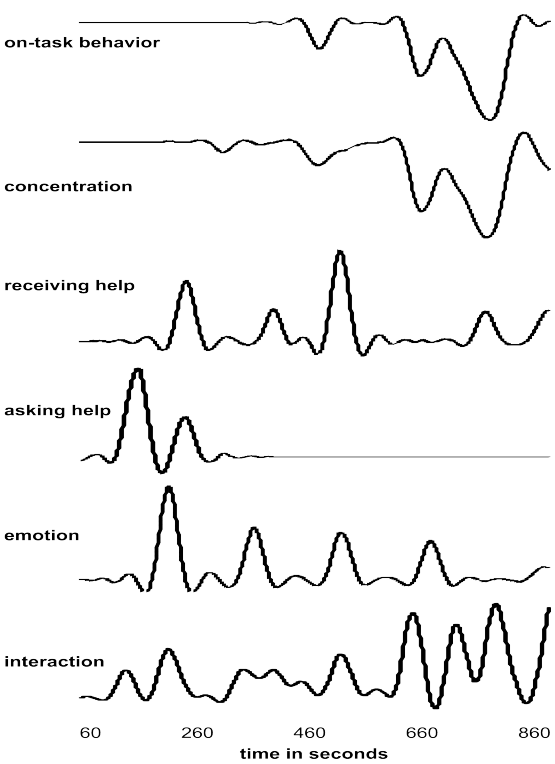

Fig. VI. Time series for child 1

Figure VI shows that during the session the child's concentration went down and his verbal interaction increased. Emotion remained reasonably constant (neutral in this case) with higher peaks (positive emotions) at the start of the session and more neutral emotions by the end. The frequency of the positive emotions declined during the session. The child asked for help at the start and received some from the supervisor during the session but played largely independently.

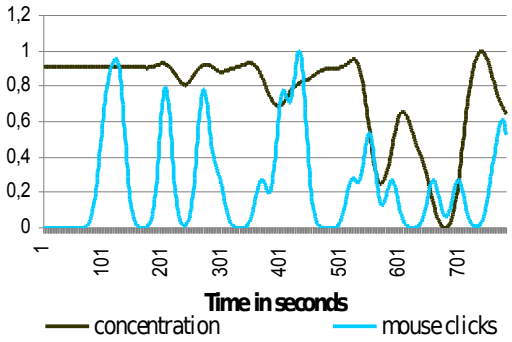

Fig. VII. Child 1: Coherence of concentration and number of mouse clicks in one session

Figure VII shows that the toddler's concentration and his number of mouse clicks both went down during the session. The peaks of the clicks correspond highly with the intensity of concentration. The first four clicks were incorrect (the child chose the wrong objects), but the following clicks were all correct (not visible in figure VII). Judging by this registration of mouse clicks, one can say there is development. There is a notable peak in the middle of the session, with many mouse clicks, but after that the concentration subsides. One possible explanation is that at this latter stage the child no longer needs to concentrate as hard to follow instructions and click on the right object: he comprehends the game. By the end of the session, there is more verbal interaction, again perhaps because the child no longer requires optimal concentration. Judging by this registration, and the observations of visible behaviour as presented in figure VI, it can be said that learning has taken place during the computer game.

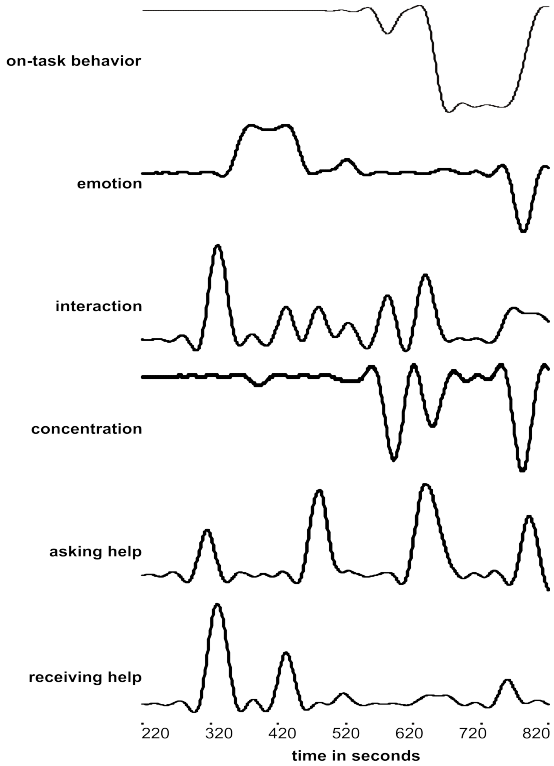

Fig. VIII. Time series for child 2

Figure VIII shows the child receiving help at the start of the session. The child interacts regularly with the supervisor throughout the session. Up until halfway, concentration is very high and constant. More information is required on his mouse clicks to explain the toddler's learning development. The toddler is working increasingly independently during the session, but the question remains whether he is performing well.

4.3 Discussion

The second study observed the on-screen learning behaviour and development of seven toddlers. New analytical methods were employed to create detailed yet easily interpretable overviews. Curve-smoothing techniques reduced the number of fluctuations, making data easier to interpret. However, one drawback of the compression that occurs with smoothing is the risk of losing important discontinuous data. Another drawback is the coding system used, which was time-consuming and therefore expensive. To acquire a significant overview of the sessions, it was necessary to study the learning behaviour in miniscule detail. In follow-up studies it may be better to code sessions not by the minute but according to events or by interval-sampling methods.

This study also focussed on learning development particularly by analyzing mouse performance (number of clicks relative to correct and incorrect clicks). One may conclude that learning development does take place during the computer game but this conclusion has to be taken cautiously. The sample was small and other relevant factors were not taken into account, including movements of the mouse, the degree of help provided by the digital playmate (a little bear; see figure I) and the kind of help provided by the supervisor. All of these are probably important in measuring performance and ultimately in learning development.

5 General discussion

According to the literature, computer-assisted learning may reduce ineffective learning behaviour. Poor development of executive functions can cause developmental delays. Computer games that are properly adapted to the developmental level of the child and not based purely on knowledge of facts (declarative knowledge) may enhance learning to learn in children. As far as we have been able to ascertain from our review of the literature, no large-scale research has been done to date on the long-term effects of computer-assisted learning on the development of learning in children. Any follow-up study should be aimed at providing an exact and clear definition of development in the *samenslim* game so that conclusions about learning to learn and learning development can be drawn more accurately. Nonetheless, the analyses conducted in our two preliminary studies clearly suggest that toddlers can and do learn during digital game sessions.

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