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Assessing children's understanding of basic time concepts through multimedia software

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Abstract

The purpose of this study is to examine the role of the computer with multimedia software in assessing the perception of the basic time concepts by children. Special multimedia software was developed, using a high level language which simulated standard time perception tests. A random sample of 374 school and pre-school age (4–11 years old) children was used in the comparative study divided into two balanced groups. Results indicated superiority in children's judgements when multimedia software was used. This superiority was most pronounced in experiments that involved motion or action. A positive correlation between age and comprehension was detected. The subject's sex or parents' occupation did not seem to make an appreciable difference. The findings of this study are discussed in terms of the applicability of computer multimedia technology, in the area of assessing the concept of time in children. © 2002 Elsevier Science Ltd. All rights reserved.

Keywords: Simulations; Evaluation of CAL systems; Media in education; Multimedia/hypermedia systems; Elementary education

1. Introduction

As many researchers have shown, the concept of time is complex and especially obscure (Block, 1989; Bromberg, 1938; Fraisse, 1984; Gruber & Voneche, 1977; Kerslake, 1975; Ornstein, 1969; Piaget, 1946/1969; Pistor, 1940; Zakay, 1989). The assessment of children's understanding this concept appears to be especially difficult.

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Most of the previous studies used different (and mutually incompatible) focal areas to assess the understanding of the meaning of time in children. Basically, these areas included: (1) time, as a consequence of fixed (consecutive, successive) time periods, (2) the development of time sense and its relationship with time period succession, (3) the relationship between time, space and speed, (4) speed events, (5) rhythmic events, (6) cyclical events, (7) alternating events not necessarily different, (8) the effect of time on things that increase (ageing), (9) past, long term memory and time perspectives, and (10) the development of the objective and subjective concept of time (Acredolo, 1989; Acredolo & Schmid, 1981; Angrilli et al., 1997; Berndt & Wood, 1974; Craik & Hay, 1999; Doob, 1971; Friedman, 1977, 1978, 1986; Gronin, 1993; Levin, 1977, 1979, 1982; Levin, Gilat, & Zelniker, 1980; Levin & Globerson, 1984; Levin, Israeli, & Darom, 1978; Lovell & Slater, 1960; Levin & Wilkening, 1989; Levin, Wilkening, & Dembo, 1984; Macar, 1996; Murray, 1969; Piaget, 1946/1969; Richards, 1982). Up until now, the measurement of the understanding of the concept of time has been achieved, on the basis of several theoretical models that were constructed by various researchers. The “tools” used by these researchers, have been essentially “conventional”, that is pictures on poster board, sound, light, chronometers, children’s toys, stimuli from computer monitors, audio stimuli from frequency generators, etc. To date, however, not many efforts have been paid to assessing the understanding of time concept with the use of computer and multimedia software.

The purpose of this research is to study the effectiveness of computers and multimedia software in assessing the understanding of basic time concepts, in contrast to the use of traditional—conventional methods of presentation.

2. Experimental methodology

2.1. Subjects

A total of 374 nursery and school-aged children took part in the research. Table 1 shows the number of subjects examined according to sex and form (which corresponds to age).

The children in question were students in three nursery schools and three elementary schools from the city of Patras, Greece (population 130,000 situated in the north-western Peloponnese). These schools were randomly selected from all the morning-session schools in the Patras area. None of the children taking part in the study had any special problems in terms of health, learning difficulties, etc., as was ascertained by checking the school records of each class selected and from discussions with the class teachers.

<table>
<thead>
<tr>
<th></th>
<th>Nursery(Age 4–5)</th>
<th>Pre-school(Age 5–6)</th>
<th>Form</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>13</td>
<td>23</td>
<td>31</td>
<td>34</td>
</tr>
<tr>
<td>Female</td>
<td>11</td>
<td>33</td>
<td>25</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>24</td>
<td>56</td>
<td>56</td>
<td>60</td>
</tr>
</tbody>
</table>
The sample comprised of 196 males and 178 female students. Their ages ranged from 4 years and 6 months to 10 years and 7 months. Table 2 shows the number of subjects, the minimum, the maximum and the average age of all subjects according to form (class) and the method of presentation used.

2.2. The pilot test

Prior to implementing the subdivision test and the actual study, a pilot test was conducted using a small number (n = 11) of children. Upon the conclusion of the pilot test, these children were excluded from the final study sample. The pilot test was conducted in order to assist in the development of an appropriate questionnaire to be used with the children to check the procedures and the experimental environment. It also allowed the researchers to have “a hands-on” opportunity to assess children’s reactions to certain procedures, language and conditions so as familiarise themselves with the work in hand both the subdivision test and main test as well.

2.3. The sample subdivision test

As already mentioned, the sample was divided into two groups across all of the age ranges and schools. The one group (the reference group) was examined using conventional methods, while the other was examined using computers and multimedia software. To ensure that the two groups were similar in terms of their understanding of time concepts, a test subdividing the sample was used.

Table 2
Subjects, minimum, maximum and mean age of the sample as per category and method of presentation of the concepts

<table>
<thead>
<tr>
<th>Category</th>
<th>Method/service</th>
<th>n</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nursery</td>
<td>Multimedia</td>
<td>12</td>
<td>4y 0m</td>
<td>5y 1m</td>
<td>4y 6m</td>
</tr>
<tr>
<td>Age (4-5)</td>
<td>Conventional</td>
<td>12</td>
<td>4y 0m</td>
<td>5y 1m</td>
<td>4y 6m</td>
</tr>
<tr>
<td>Preschool</td>
<td>Multimedia</td>
<td>28</td>
<td>5y 2m</td>
<td>6y 4m</td>
<td>5y 8m</td>
</tr>
<tr>
<td>Age (5-6)</td>
<td>Conventional</td>
<td>28</td>
<td>5y 2m</td>
<td>6y 3m</td>
<td>5y 9m</td>
</tr>
<tr>
<td>Form A</td>
<td>Multimedia</td>
<td>28</td>
<td>6y 1m</td>
<td>7y 1m</td>
<td>6y 8m</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>28</td>
<td>6y 1m</td>
<td>7y 1m</td>
<td>6y 8m</td>
</tr>
<tr>
<td>Form B</td>
<td>Multimedia</td>
<td>30</td>
<td>7y 2m</td>
<td>8y 2m</td>
<td>7y 7m</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>30</td>
<td>7y 1m</td>
<td>8y 0m</td>
<td>7y 8m</td>
</tr>
<tr>
<td>Form C</td>
<td>Multimedia</td>
<td>29</td>
<td>8y 1m</td>
<td>9y 2m</td>
<td>8y 8m</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>29</td>
<td>8y 1m</td>
<td>9y 2m</td>
<td>8y 8m</td>
</tr>
<tr>
<td>Form D</td>
<td>Multimedia</td>
<td>31</td>
<td>9y 0m</td>
<td>10y 3m</td>
<td>9y 9m</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>31</td>
<td>9y 1m</td>
<td>10y 3m</td>
<td>9y 8m</td>
</tr>
<tr>
<td>Form E</td>
<td>Multimedia</td>
<td>29</td>
<td>10y 1m</td>
<td>11y 0m</td>
<td>10y 7m</td>
</tr>
<tr>
<td></td>
<td>Conventional</td>
<td>29</td>
<td>10y 3m</td>
<td>11y 1m</td>
<td>10y 7m</td>
</tr>
</tbody>
</table>

y, years, m, months.
Each age category (4–5, 5–6, A, B, C, D, E) was subdivided into two groups, by using as criterion the results of subdivide pre-test. This pre-test, gave a score for every child based on the number of correct answers. The sample was then divided so as to have two groups matching as much as possible in relation to the scores achieved while keeping all other characteristics unaffected. The experiments for subdividing the sample were carried out about a month before the main experimental tests and involved the use of specifically constructed software.

The time taken to present the software content and to get the child’s response was about 15 min per child. The procedure followed was precisely the same as the one for the main tests.

The tests described:

Experiment 1: Time assessment through a sequence of events.
Process: On the computer screen 32 different pictures were displayed in succession. They depicted a wall in various stages of its construction. Five of these appeared on the screen in a random order and the subject was asked to place these five pictures in the correct chronological order.

Experiment 2: Age assessment.
Process: The child was presented with four pictures of swallows. The subject was asked if it recognised the subject depicted in each one. In case of difficulty, the researcher offered help up until the subject of each picture was fully understood. The first picture was of a nest with eggs and the next had the shallows already flying out of the nest. The sitting on the eggs (before they hatched) came next while the last picture had the parent birds feeding the chicks newly born inside their nest.

Each child was asked to chronologically order the pictures.

Experiment 3: Assessing the development of the concept of “internal time”; it concerned events in which the child was not directly involved.
Process: Each child was asked to compare two time intervals. The duration of each one of those was being the same (12.5 s). During the first interval a grey and featureless screen was displayed and the child had no other activity. During the second interval video clips were displayed.

Experiment 4: Assessing the time concept by considering periodically repeated every-day events.
Process: Four pictures of a girl appeared on the screen. The first depicted a sleeping girl at sunrise and the second showed the girl reading during the night. The third had the girl attending school lessons while the last had the girl leaving home to go to school. The subject was asked to recognise the content of each picture. In case of difficulty, the researcher offered help up until the subject of each picture was fully understood. The subject was then asked to place the pictures in the correct chronological order.

Experiment 5: Assessing children’s understanding the relation between time, distance and speed.
Process: A “race” between two snails took place in real time on the computer screen (animation). They both covered the same distance to the finish, though one was slower. The child was asked his opinion as to if the snails raced for the same length of time or not.
Experiment 6: Length of time assessment relating the ordering of time intervals while avoiding the interference of misleading spatial stimulation.  
Process: Two brightly lit squares (3.5 x 3.5 cm) were made to appear in the middle of computer screen. They were 1.5 cm apart and coloured green and orange, respectively. The green light came up first (brightly illuminated). The orange came up 2 s later and 3 s after this event both lights were “turned off”. The green light was on for 5 s in total, while the orange for 3 s. The following questions were asked:  
(a) Did the lights come on together or was it, perhaps, that one came on before the other?  
(b) Did both lights come off together or not?  
(c) Did one of these two remain on for a longer period of time than the other?  

2.4. The main experimental procedure  
The research team was appropriately trained for the purpose of conducting the study. The examination of the children was always conducted at the schools the children attended and always during morning hours. The rooms, in which the children were tested, were specially transformed so that individual test could be carried out. The presentation of the experiments, either using conventional methods or multimedia, were conducted at the same time by two researchers (in separate rooms). Each day they alternated between the two sample groups. The study lasted for 4 months (February–May 1997) while the examination for each student lasted 50 min, approximately.  
A total of six experiments were conducted with each child. The time concepts that were examined during the main test were: (1) simultaneity; (2) equality of synchronous intervals; (3) order of events; (4) concept of age (with visual background); (5) the cyclical aspects of time at rhythmic and periodic events with small periods; and (6) the cyclical aspects of time at periodic events with large periods, and the time in perspective.  
The experiment procedure as well as the setting was constant from every student according the “latin square” method (Aronson, Ellsworth, Carlsmith, & Gonzales, 1990). While conducting the study, the two researchers were involved with the same age group category, so that errors attributed to the researcher influence could be checked (Christensen, 1988).  
Children were tested in separate rooms according to the method of presentation. The test was continuous and nobody else intervened during testing. A short discussion about each child’s interests always proceeded the test so as to create a friendly atmosphere (Kosmopoulos, 1983). Every child in the group using multimedia software was acclimatised individually to the presentation environment prior the conducting the experiment. Specific demographic information, such as student’s age and father’s occupation was confirmed by the school. All the answers given as well as the more general information solicited from each student’s teacher were recorded on paper (using a special questionnaire) at the time the data were collected.  
For the reference group presentation, among the conventional experimental means used, were: children’s toys, electric and electronic accessories, time switches, chronometers, transparent glass containers and test tubes, picture cards, etc. These tools were chosen or specially constructed by the researchers. They were modelled as closely as possible on the descriptions of the apparatus used by earlier researchers (Friedman, 1977; Levin, 1977, 1979; Piaget, 1946/1969).
2.5. Emulation software design and development

An IBM compatible computer utilizing a standard sound card selected for the presentation of the experiments. The display sub-system utilised a 15 inch CRT display working on full colour at a 800×600 pixel resolution. A standard MS-Windows operating system was used with multimedia extensions. The software was especially developed using Microsoft's high level object-based programming language Visual Basic 3.0, Professional Edition. The software was event driven, mouse-based and designed to be user friendly. Elements that could distract the child from the object of the study were avoided. The content of the experiments presented using multimedia software was practically the same as the one with the experiments presented using conventional methods, although liberal use of multimedia effects was made.

2.6. Description of main experimental tests

2.6.1. Experiment 1: simultaneity

The investigation in this test concerned whether the children had developed:

1. Time and space co-ordination (simultaneous) while misleading spatial factors interfered.
2. A basic understanding of duration of time.

Procedure: Using conventional experimental arrangements as well as a computer simulation, water was allowed to flow from a large capacity container through an upside-down "Y" tube. The final pipes were exactly the same in terms of diameter and length. The water was collected in a test tube A, and in a cylindrical cup, B. The base area of B, was double than the one for A (see Fig. 1).

With the use of the computer, a sound of flowing water was generated as the water was flowing from the big container to the two smaller ones. At the end of each test, which lasted for about 25 s, the quantity of water in containers A and B was equal.

The test was initially demonstrated once to each child. Afterwards, the test was repeated once more and the child was asked the following questions:

(a) Did the water start flowing into the two containers simultaneously?
(b) Did the water stop flowing into the two containers simultaneously?
(c1) How long did the water take to get from the bottom (of the test tube) to the top (while pointing at the tube)? Please give me an estimate: 15, 20, 25, 30, 35 seconds. What do you think?
(c2) How long did the water take to get from the bottom (of the cup) to the top (while pointing at the cup)? Please give me an estimate: 15, 20, 25, 30, 35 seconds. What do you think?

If the child answered questions (a) and (b) right, he/she was asked further questions, as follows:

(d) Have the two containers now got the same amount of water?
(e1) If I were to pour the water from the tall container (pointing to A) into an empty glass, same as this short one over here (pointing to B), would the two glasses (the new glass and the short one over here) have the same amount of water?
If the child answered the question (c1) affirmatively, the following question was put to him/her:

(e2) How did you gather that?

Questions c1 and c2 did not aim at assessing whether the child could estimate the duration of time (expressed in seconds), but whether (and to what extent) he/she could grasp that the duration of flow was (for both containers) equal. Irrespective of the time selected it was counted as "correct" if this was satisfied.

2.6.2. Experiment 2: equality of synchronous intervals

The main aim of this test was examine whether the children had the ability to compare the duration of time between two events taking place simultaneously while misleading factors (e.g. distance and speed) interfered with their judgement.

Procedure: In the assessment of the concept of equality of synchronous intervals, two trains running parallel to each other were employed. In the experiment using conventional methods, two real-life toy (electric) trains were used (a red and a blue one), running on 2.1 m long rails. These were placed on a table, right in front of the child. In the experiment using multimedia software, two trains (red and blue, respectively) run parallel to each other, across the width of the computer monitor. Characteristic train sounds accompanied the image of the moving trains. These were identical except for their colour. They both started and finished simultaneously. When they started, the red train was in front of the blue one, while it was behind it when they stopped (Fig. 2). The blue train travelled, therefore, faster and covered a longer distance than the red one. The start and the end of the movement were signified by a clicking sound while engine sound accompanied train movements.
The same effect was experienced using computer simulation: two coloured trains (red and blue) “ran” on two parallel rails in a parallel direction. However, music could be heard before the trains were put to motion, which stopped immediately as trains started moving. It started again after they stopped moving. A particularly realistic sound of moving trains accompanied their movement.

Initially this test was performed once for each child, and lasted 12 s. Afterwards, the trains “raced” successively for 12, 25 and 50 s, respectively. After each and every race the child was asked the following questions:

(a) Did the trains start running at the same time?
(b) Did the trains stop running at the same time?
(c) Have the two trains covered the same distance in the same time?
(d) Has one of the trains run for a longer time than the other?
(e) Did one of the trains start moving after the other?

Dependent on the duration of the experiment, a train whistle could be heard whistling between one and five times during the course of the movement. Additionally, at the start and the end of the movement, two labels with the word, “train stop” appeared.

2.6.3. Experiment 3: Order of events

In this experiment it was investigated whether the children are able to understand time in terms of consequence of events taking place.

Procedure: Using conventional experimental tools as well as a computer, water was transferred from a short but large container (cup) through a short pipe into a tall measuring cylinder (glass). Both containers were marked at different highs, all along their circumference (Fig. 3). Both containers, the cup and the glass, were of the same capacity while the amount of water between two consecutive marks in the first container was equal to the amount of water between two consecutive marks in the second. Of course, the distance between the horizontal marks on the tall glass was larger (due to its' smaller diameter) than those on the wider cup. Let’s consider that the marks on the cup were represented by 11, 12, ..., 16 from top to bottom and on the cup by 111, 112, ..., 116 from bottom to top. Before each question was asked, the experiment was demonstrated twice, to ensure that all subjects paid attention. The total time of water flow from the cup to the glass was about 28 s. Using the special software, every time the water was flowing from one container to the other, a characteristic realistic sound of its flow was generated. The opening and closing of the valve was also accompanied by the generation of a special sound.

Afterwards, each student was asked the following questions, each question being preceded by a new appropriate demonstration:

![Fig. 2. Starting and finishing points of the trains](image-url)
(a) Did the water take the same time to go from point I1 (pointing to the appropriate mark) to point I2 as it took to go from point III1 to point II2?

(b) Did the water take longer time to go from point I1 to point I3 or did it take longer time to go from point I1 to point I2?

Using conventional experimental arrangements after the experiment was executed once, six pictures (depicting both containers) were shown to each child in a random order.

Precisely, the same procedure was followed with the use of the computer. That is, after an appropriate demonstration and after the impression was given (by computer simulation) that the containers were “photographed” at certain points in time, each child was presented with a group of six pictures of the two containers.

Each picture showed the containers at different phases, as the water was flowing from the one container to the other, passing through the consecutive stages (I1, I2 in the one container and III1, II2 in the other, etc., until the cup was empty and the glass was filled up). The initial picture of the full cup and the empty glass as well as the final picture of the empty cup and the full glass was included in these six pictures.

![Diagram of containers and screen](image)

Fig. 3. The containers and the screen of the third test.
The researcher asked the child to place these pictures in a logical order showing that the cup was full before it was emptied while the glass was empty before it was filled up. The following question was asked:

(e) *Here are some pictures of the containers. Can you place them in an order from left to right so as to show that the cup (top container) was full before it was emptied?*

Afterwards, with the use of conventional experimental arrangements 12 printed pictures were presented (six of the cup and six of the glass), which were placed randomly in two separate rows. The pictures (of either the cup or the glass) were shown to the children in random order at a steady rate. Exactly the same happened when the computer was used.

Each child was once again asked to attempt to place the pictures in *pairs* (in the vertical sense), so as to show that the water was transferred from the cup to the glass. In other words, to show that the cup was full before it was emptied while the glass was empty before it was filled up. The comments and the question asked were:

(d) *Here are some pictures of the containers. Can you place them in such an order from left to right so as to show to me, like you did before, that the cup (the top container) was full and then empty?*

Finally, after the experiment was executed once, each child was asked to answer the following question:

(e) *Was the time necessary for this container (pointing to the cup) to empty, equal to the time necessary for this container (pointing to the glass) to be filled up?*

If the answer was “yes”:

(f) *How did you gather that?*

2.6.4. Experiment 4: Concept of age (as related to various visual clues)

This experiment explored the possibility of the children perceiving the meaning of age using static visual information, when misleading factors of size and shape were involved.

Procedure: Each child was shown two pictures on separate cards, one of a pear tree and one of a cypress tree. Exactly the same happened when the computer was used. The pear tree was short with many extended branches, while the cypress tree was tall with less extended branches. There were many leaves on the branches giving the impression that it was spring. Just by looking at the two pictures of the two different trees, no logical conclusion could be drawn as to which tree was older. Using conventional experimental tools the pictures were placed in front of the student or alternatively they were shown on a computer screen by means of multimedia software. The pictures did not have start-up or stopping points, which would allow for enhancement or clarification when designing the multimedia software.
The order by which the pictures were presented to the children changed from child to child (to even out systematic errors).

The question asked was:

*Look at these two trees carefully. Do you think they are of the same age?*

2.6.5. Experiment 5: The cyclical aspects of time in rhythmic-periodic events with short periods

This experiment aimed at exploring whether children had developed a perception of the cyclical-periodic aspects of time. A rhythmic-periodic phenomenon of a short duration was used. The understanding of this concept was then examined in relation to the functional ability of children to order shapes, which represented parts of a period. The influence of misleading stimuli was also examined.

Procedure: Using conventional experimental procedures, the researcher presented to the child a model card with a sine-wave form and pointed to the child to note how the line moves upwards in the white area and downwards in the grey area of the card (Fig. 4). The model-card was placed to the left of the student. The researcher then presented the four isolated quarters of the full period of the oscillating wave, each one in a different picture. The order of the pictures was random but varied from child to child (to even out systematic errors). The child was asked to place the pictures of the four phases in a correct order, so as the complete period of the oscillating wave would be produced.

Using multimedia software, a “particle” moving along a sinusoidal curve appeared on the screen of the computer accompanied by music. The “particle” movement started from the left edge of the screen and stopped at the right side, leaving along a trail of its movement. When the “particle” reached the right-hand side of the screen it would start moving again from the left but the trail it left would now be of a different colour (Fig. 4). The speed of movement and the wavelength were adjustable. After that, four parts of the complete period of the oscillating wave were depicted in isolation on the lower part of the screen. These were on four different cards, placed at a random order. The experimenter asked the child to place these cards in the correct order so as to produce the complete period of the oscillating wave. The clues given and the question asked in each case were:

(a) *Notice how the line goes up in the white area (while pointing), comes down in the grey one, goes up again in the white area, goes down again in the grey one, and this goes on and on. Could you possibly put these four pictures in a correct order from left to right to show how the line goes up in the white area and then down in the grey, how a wave is produced, in other words?*

Using conventional arrangements, the researcher pointed out to the child that the grey part of these cards will have to be placed below, same as in the model-card. If a child mindlessly placed the cards at random, the experimenter would offer another chance by shuffling them again and asking the child to re-order them. This procedure was also repeated as necessary when experiments
with multimedia were done, up until it was clear (in both cases) that the child had ordered the cards to the best of his/her ability, irrespective of whether it was the correct one or not. After this test, the experimenter asked the child to judge three times the correctness of three alternative orderings of these four cards. The experimenter would repeatedly ask the following question in each one of the three cases:

(b) *Are these four pictures in the correct order so as to make a wave?*

The first two orderings were correct cyclic permutations. The third was wrong, non-cyclic permutation.

2.6.6. **Experiment 6: The cyclical aspects of time using periodic events with large periods, and the long-term perspective of time**

This experiment aimed at exploring whether the children had developed a perception of the cyclical aspects of time (cyclical time-events) in relation to a long-term perspective of time.

*Procedures:* With the aid of conventional experimental arrangements the researcher showed the child four pictures in a random but steady order. Each picture was distinctive and it was clear that it was a picture of one of the four seasons. Consequently, the researcher asked the child to tell him what the picture showed while helping him/her to recognise them (if the child had any difficulty in doing so). With the help of the multimedia software, the same four pictures were brought on the computer screen in a random order. The researcher also offered help if the child had any difficulty. This could be done by clicking the “mouse” on each picture and, in doing so, a sound could be heard, different for each season and “matching” it. Finally the child was asked to place the pictures in a logical order from left to right.

The clues and the question asked to each child (on both methods of experimentation) were as follows:

(a) *These are pictures of the four seasons. Can you put them in an order from left to right so as to show me in which order the seasons come?*

![Fig. 4. The model card of the fifth test.](image-url)
Any cyclic permutation of the pictures was accepted as correct, independently of the starting picture, as long as their succession was correct. If a child ordered them at random, the researcher would re-shuffle them and would give him another chance. This procedure was repeated (for both methods of experimentation) until it was clear that the child had ordered the cards in a certain order to the best of his/her ability, irrespective of whether the order was the correct one or not.

After that, the researcher asked the child to judge the correctness of three alternative orderings of these four cards. The experimenter would ask the following question in each one of the three cases:

b) *Is the order of these pictures correct? Is it possible for the seasons to come in this order?*

The first two were correct cyclic permutations. The third was wrong, non-cyclic permutation. Overall, no movement or special sound could be utilised to enhance the action of the use of the multimedia software during this experiment.

2.7. **Quantifying the data taken**

To process the data in a quantitative way the following procedure was followed. An integer number expressed the children's answers to each question. There were six experiments in total, but each experiment had a different number of questions involved. Each experiment was testing a different and independent aspect of child's perception of time and it was considered proper to accept each experiment as having equal importance. In effect, the same "points" should be awarded as a maximum score to each of the experiments.

By taking the least common multiple integer of the number of questions of each experiment (which is 30), every one of the six experiments was graded from a minimum zero up to a maximum of 30 points. This way, the sum total of points from all six experiments varied (for each child) from zero (minimum—where none of the answers was correct), up to $30 \times 6 = 180$ points (maximum—where all the answers were correct).

Within each experiment, each question was awarded equal number of points. This could always be a positive integer as by multiplying this with the number of questions in the experiment, would always result in 30.

The detailed logic of the algorithm developed, allocating the 30 points to each question of every experiment is the following:

**Experiment 1:** The correct answers to questions (a), (b) and (d) were marked with 6 points each. Six points were also given for correct answers to questions (c1) and (c2) jointly. Similarly, 6 points were given to every child that answered both questions (e1)–(e2) correctly, while no points if he/she did not answer correctly. This last was decided as it was observed that many children answered affirmatively to the first of these questions (e1) thoughtlessly and without deliberation. This did not testify any knowledge related to the concept under investigation and was rather related to the equal size of the two containers as opposed to the amount of liquid contained.

**Experiment 2:** Correct answers to questions (a)–(c) were given 6 points each.
Experiment 3: Correct answers to questions (a)–(f) were marked with 5 points each. It was decided that questions (e) and (f) were to be marked independently due to the fact that answering question (e), [which is also the answer to question (f)], required something more than just perception.

Experiment 4: The correct answer to the single question was given all 30 points.

Experiments 5–6: The correct answer to question (a) was marked with 15 points. Every time a child recognised one of the three permutations (b1, b2, b3) correctly, he/she got 5 points. However, no points were given for the last question (b3) when the child did not answer both the two previous questions (b1, b2) correctly.

3. Data analysis

In the previous paragraph, a full description of the experimental methods was given. It can be noted that the groups were balanced, a pre-test was performed, the data collection was carefully controlled, the questioning was randomly ordered when applicable and finally the researchers tested the two groups as equally as possible, and presented them with the same questions as closely as possible. All these precautions were taken in order to minimise systematic errors in this study. Keeping all these in mind it can be estimated that any remaining systematic error in the data is of a different order of magnitude than the statistical error, and in any case a lot smaller than these. The contribution of systematics in the total errors is therefore judged to be insignificant. In the following discussion, therefore only statistical errors will be considered.

At the beginning of the analysis, the following two tests were employed in order to statistically analyse the children’s responses between the two methods of examination of the basic time concepts (Loftus & Loftus, 1988):

1. t-test to compare in general the two examination methods. This test performed separately for each experiment. A different t-value test was performed for each age group category.
2. t-test to examine the existence of differences in the performance of the children, amongst the two examination methods. This was performed separately for each experiment, but for the total student sample and irrespective of the age group.

The overall findings indicated that children who were examined using the multimedia software had better ratings in terms of giving correct answers than those who were examined employing conventional methods. This can be seen in Table 3, from the differences found between the different methods used, without differentiating the children by age in the entire sample.

Table 3
The differences in children’s overall responses between the two methods of examination (computer vs. non-computer testing; n = 374)

<table>
<thead>
<tr>
<th>Experiment</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>P value</td>
<td>0.000*</td>
<td>0.000*</td>
<td>0.003*</td>
<td>0.605</td>
<td>0.000*</td>
<td>0.075</td>
</tr>
</tbody>
</table>

*P < 0.05.
As it can be derived by examining the results shown in Table 1, which compare the two different presentation methods, statistically significant differences can be found in experiments 1, 2, 3, and 5.

The same was evident when we examined analytically the responses of each age group category (Table 4).

In several instances, the $P$ values in Table 4, indicate statistically significant differences between the two methods of examination employed. This is especially true in most experiments with older children.

Looking at Table 4, we observe (in various bins) various definite trends appearing. These trends are below the level of statistical significance due to the subdivision of the number of children in each bin, some of which can be as low as 28 or even 12 (for each sub-group). Nevertheless the trends are real.

In summary, we found that the percentage of correct responses given by the children when assessed using multimedia software was significantly higher than when the assessment was done using conventional means.

However, this was especially evident in some of the experiments (1, 2, 3, 5 and not in 4 and 6). Trying to explain the reason for this, we can reconsider these experiments: We see that the main characteristic of experiments 1, 2, 3, and 5 was that movement was involved (fluid flow, train movement, waving movement of a point on the screen) as well as the use of graphics. When using multimedia software as an integral factor of the movement depicted, sound or music was used at the starting and ending points of the movement. In several instances the sound accompanied the movement only and ended when the movement stopped. In the fourth as well as the sixth experiment no movement was involved, inherent to the experiment. Therefore, the multimedia software only made use of music, executed during the test.

More specifically, the first and third experiments had an inherent disadvantage when performed using real tubes and water. Generally, if fluid is moved from one container that is located on top of another through the use of a pipe, the quantity of water that passes from the one container to the other does not remain constant during the duration of the entire flow. This occurs because the quantity of water that passes through the joint is dependent not only on the cross-section of the pipe but of the height of the water in the upper container. However, the height of this water continually decreases, as the volume of the water decreases in the upper container. The result is that as the speed of the descending water level (surface) of the upper container does not remain constant, then neither does the speed of movement of the water level in the lower container.

**Table 4**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Nursery</th>
<th>Pre-school</th>
<th>Form A</th>
<th>Form B</th>
<th>Form C</th>
<th>Form D</th>
<th>Form E</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.071</td>
<td>0.041*</td>
<td>0.181</td>
<td>0.019*</td>
<td>0.133</td>
<td>0.004*</td>
<td>0.015*</td>
</tr>
<tr>
<td>2</td>
<td>0.116</td>
<td>0.178</td>
<td>0.078</td>
<td>0.112</td>
<td>0.154</td>
<td>0.247</td>
<td>0.015*</td>
</tr>
<tr>
<td>3</td>
<td>0.145</td>
<td>0.108</td>
<td>0.244</td>
<td>0.213</td>
<td>0.058</td>
<td>0.116</td>
<td>0.046*</td>
</tr>
<tr>
<td>4</td>
<td>–</td>
<td>–</td>
<td>0.166</td>
<td>0.694</td>
<td>1.000</td>
<td>0.797</td>
<td>0.797</td>
</tr>
<tr>
<td>5</td>
<td>0.054</td>
<td>0.052</td>
<td>0.032*</td>
<td>0.150</td>
<td>0.050</td>
<td>0.171</td>
<td>0.010*</td>
</tr>
<tr>
<td>6</td>
<td>0.923</td>
<td>0.318</td>
<td>0.283</td>
<td>0.461</td>
<td>0.380</td>
<td>0.299</td>
<td>0.714</td>
</tr>
</tbody>
</table>

* $P < 0.05.$
Thus, in these two experiments when using conventional methods, the speed of the descending water level (surface) of the upper container did not remain constant, neither did the elevation speed of the water level in the lower container remain constant with the passing of time. This factor, however, can be misleading in terms of children’s understanding and suggests a systematic error inherent in experiments using conventional methods. Naturally this is an undesirable phenomenon that cannot be avoided completely. With the use of multimedia this problem disappears.

In the comparable multimedia simulations, the descent-speed of the water level in the upper container (and the corresponding elevation-speed of the water level in the lower container) remained constant. It cannot be argued that this misleading factor is decisively impairing the judgement of the child. However, when we want to measure with accuracy the child’s knowledge, any misleading stimuli result in influences that are always detrimental.

Other characteristics of the experiments are as follows. Using conventional methods, the start of the flow of the fluid was set manually by the researcher opening the valve. What followed was the natural, characteristic sound of water flowing. Using multimedia, as the water started to flow, the characteristic “clicking” noise of a valve opening was heard. In conjunction with the “flow” of water that could be seen, a clear characteristic sound of water flowing could be heard. This sound stopped as soon as the flow of the water stopped.

The quality of the data taken as well as the assessment of our first findings (earlier) led us to conclude that further and deeper data analysis was both possible and desirable. A full multiple regression analysis was, therefore, performed in order to verify all the earlier findings and to examine the influence of certain factors affecting children’s understanding of basic time concepts. Such factors examined were age, sex, father’s occupation, and method of research. A linear regression model was used, as the shape of the data plotted seem to fit this. The following form of the linear additive model was used (and tested with the aid of the multiple regression analysis):

\[ U = a + b_1 \times S + b_2 \times A + b_3 \times W + b_4 \times M \]

where: \( U \) is understanding (data taken), \( S \) sex, \( A \) age, \( W \) father’s occupation, and \( M \) the examination method used. It has been observed by us, that school performance did have a positive correlation to the understanding of time concepts. However, this factor was not used in the earlier model, as some students in our sample were so young that school performance was thought to be influenced by various factors and was likely to change later, anyway.

Table 5

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Method-coefficient ( b_4 )</th>
<th>Age-coefficient ( b_2 )</th>
<th>( R^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>54.390*</td>
<td>3.771*</td>
<td>0.426</td>
</tr>
<tr>
<td>2</td>
<td>39.000*</td>
<td>1.911*</td>
<td>0.205</td>
</tr>
<tr>
<td>3</td>
<td>34.662*</td>
<td>3.389*</td>
<td>0.457</td>
</tr>
<tr>
<td>4</td>
<td>-7.679</td>
<td>2.943*</td>
<td>0.161</td>
</tr>
<tr>
<td>5</td>
<td>56.071*</td>
<td>2.899*</td>
<td>0.306</td>
</tr>
<tr>
<td>6</td>
<td>27.403*</td>
<td>3.404*</td>
<td>0.282</td>
</tr>
</tbody>
</table>

\*\( P < 0.05 \).
Table 5 shows the results of the multiple regression analysis. More specifically, it shows the values of the regression coefficient $b$ related to age, the statistical significance as well as the coefficient $R^2$ per experiment.

From the values contained in Table 5, it is evident that there are statistically significant correlations differences between the answers the children gave (e.g. score achieved) and method of examination as well as the age of the student. However, no statistically significant differences were noted when sex and father’s occupation were examined. Finally, the fit of the linear additive model to our sample seems generally good.

4. Experimental findings and discussion

In conclusion, we can assert that the presentation method employing the use of multimedia (instead of using conventional methods and appurtenances) is preferable when:

1. The environment through which the time concept is examined is not static but involves movement or changes.
2. There are facets, which can be emphasised through the use of multimedia (graphics, movement, music, etc.) so as to assist the child and to avoid misleading its judgement.
3. A high degree of accuracy and precision is called for, when trying to avoid the introduction of unrelated details likely to mislead the child.

For all younger ages (4–5 and 5–6), when the visual and verbal information was combined with sound information, in this multimedia software, better results have (perhaps) been achieved. The child, through the use of multimedia software, can acquire information in quite a few different ways. The assistance in their decision making as offered by the software, does not appear to affect the child’s decision. It, rather, facilitates the decision-making process by making the question clearer, “cleaner” and (in the end) easier to comprehend.

We can, therefore, safely conclude that the results of this “conventional” vs. “multimedia software” comparison are not restricted to the confines of this study but have a more general field of application.

This study demonstrates that a quantifiable enhancement is offered in student’s comprehension, when simulation techniques with multimedia effects are used. The reason for this enhancement of comprehension is explained in this study and it also seems to be dependent on the particular subject taught (or examined). In any case, as an overall improvement, it can be claimed that the techniques described, offer significant help to the students. Such techniques should, therefore, be exploited whenever possible when educational software is designed and produced.

References


