# Do computers improve the drawing of a geometrical figure for 10 year-old children?

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## Abstract

Nowadays, computer aided design (CAD) is widely used by designers. Would children learn to draw more easily and more efficiently if they were taught with computerised tools? To answer this question, we made an experiment designed to compare two methods for children to do the same drawing: the classical 'pen and paper' method and a CAD method. We asked two groups of 14 children to draw a geometrical figure: the Rey-Osterrieth Complex Figure (ROCF). The first group drew it with a pen on a sheet of paper ('paper' group) and the second on a computer screen with CAD software ('computer' group). Two drawing conditions were studied: 'Copying' the figure and drawing from memory. Results showed that the 'computer' group was better at copying the figure but that both groups performed equally well when the figure was drawn from memory. These preliminary results suggest that using a CAD tool could help children while they copy a model, but that it does not improve their ability to draw the same figure using their own, internal model.

*Keywords: Drawing, Learning, Computer, children*

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## Introduction

For many years, professional drawing practices have been dramatically changing. Nowadays, computer aided design (CAD) is widely used to express the creativity of graphic designers. Designing now requires using a graphic tablet and a mouse or a stylus coupled with graphic software allowing us to touch up images, vectorisation, or 3D drawing. Both the drawing conception and the manual involvement change when these new tools are used. As a matter of fact, most of the software allows us to draw forms as if they were distinct elements which are not automatically fused when they overlap. It is thus possible to produce complex forms by simply superposing basic elements. These elements can still be modified separately and it is also possible, to move or to transform one of them without changing the others. In addition, the 'copy/paste' and the 'undo' tools make the trial and error procedure much less costly in time and energy than in the traditional pen and paper drawing. In short, using CAD drastically changes the design process. Furthermore, the manual actions also change in CAD. This is obvious when a mouse is used instead of a pen. Even when a pen is used in association with a graphic tablet, the actions achieved with the pen can be quite different with respect to those traditionally done with a real pen. For instance, very often the basic elements composing the drawing are selected in a library of ready-made shapes. They are then dragged to their correct location where they can be modified in shape, size and orientation by clicking on a particular point of the shape and selecting the appropriate procedure in the 'toolbox' menu. Finally, thanks to the graphical toolbox, a unique tool, the mouse or the pen can replace the pencil, the brush, a quill and even the eraser!

In spite of all these advantages, in the early 80's, when CAD was being introduced in design offices, surveys conducted among draftsmen showed that they were not totally satisfied with computers (Lebahar, 1985; Ulmann et al., 1989; Whitefield 1986). Although they appreciated their speed and accuracy and the ease of making modifications allowing for very fast product development, they were less satisfied when they had to design a highly complex shape. In such cases, they often preferred to go back to hand-drawing with a good old pencil at the rough draft stage, before resuming designing with the computer, as if there were a cognitive benefit in 'thinking with a pencil'. In other words, these new graphical tools change drawing habits but do they really make drawing easier? Another question may be raised: is it necessary to be a good designer with the 'pen and paper' in the first place, in order to efficiently use the computer graphics tools? If the answer is yes, then teaching design should begin with classical 'pen and paper' training for acquiring the basic drawing skills. New technologies should then be used afterwards, following this initial step. If, however, initial training in classical drawing is not strictly required for efficiently using the new technologies, then one might wonder why the initial teaching of drawing at school for children could not be done with the new technologies. Would this make teaching and learning drawing easier or on the contrary, more difficult?

As pointed out by Kirschenmann (2001), there is no doubt we are in a 'digital' and 'media-dominated' environment and teachers should take into account the availability of new tools for teaching in general, and for artistic teaching in particular. The influence of software on education has been questioned for a long time and, as early as 1970 for instance; Danver suggested that computers might be very useful as a teaching device in high school. The debate about using computers for learning widened rapidly in the 80s, following Papert's work (1980; 1994).

In this framework, the computer programme did not manage the learning progress of students, but conversely the students themselves programmed the machine. The system was under the control of the user. The learners were immersed in a "microworld", the best example being the “logo turtle”. The instructions that students gave to the machine during the exploration of the microworld provided useful information regarding how they built knowledge about this microworld. This paradigm has generated work in various fields: geometry, physics, technology (flying robots), grammar...

Yet, studies devoted to the impact of computers on children learning to draw are still very sparse. Of course, children drawing per se have been widely studied (e.g. Leif and Delay, 1965; Luquet, 1967; Davido 1976; Wallon, 2003) and the different steps in mental representation in relation to the different steps in psychic and affective evolution have been widely described. However, the impact of 'school teaching' and pedagogy on the development of drawing itself is still unclear. Recent works have highlighted the role of aesthetic education (Acer, 2008) and works of art observation (Eckhoff, 2008) on aesthetic judgment in children. However, if one makes an exception for the pioneering study of Anning (1997) on learning drawing in primary school, the impact of new technologies and the question of the ergonomics of the tool used for teaching drawing to children has not been extensively studied.

Because it is very simple to use, design software offers the possibility of drawing complex designs without being an expert designer, particularly for young children whose motor control of fine and precise hand movements is not completely mastered. Children can then express themselves more freely and be able to produce better designs more easily than with pen and paper. Consequently, if their designs become better and more sophisticated, their perceptual capacities and their aptitude in building correct and coherent spatial representations might increase. This is the positive point of view. Conversely, according to the negative point of view, using the new technologies reduces manual activities with respect to traditional ones (Poitou, 1992). The great reduction and simplification of the movements when drawing with a computer could reduce both the sensory-motor and the spatial competence of the children. As a matter of fact, taking ready-made geometrical forms in a toolbox, dragging them with a mouse and resizing them by simply clicking and pulling on a corner makes the activity much more abstract than when one has to draw the forms 'ex nihilo' with a pencil. Drawing a rectangle with a pencil requires making a movement which totally and exactly describes and matches the visual form of the rectangle. The relationship between the visual form and the movement is direct and unique: in that sense we can say it is 'concrete'. This is not the case with CAD where this relationship is more 'abstract'.

The same problem was raised for the learning of handwriting versus typewriting and their respective impact on the visual recognition of letters (Velay et al., 2004; Velay & Longcamp, in press; Mangen & Velay, 2010). It has been shown in children (Longcamp et al., 2005) and in adults (Longcamp et al., 2006; 2008) that character recognition was better when the characters had been learned by handwriting than when they had been learned through typewriting.

Our work stands in the framework of the Clark / Kozma debate that developed in the 1980s-1990s. The question in hand was to determine the impact of new technologies on learning. On the basis of comparative experimental work, Clark (1983, 1994) claimed that computers do not influence the learning process. In his opinion, media were only vehicles for information transmission that did not help students in building knowledge. Better performance when using computers was possibly explained by factors such as: greater motivation in students and teachers, lessons better prepared, increased attention linked to the novelty of the context and tools… By contrast, Kozma (1991; 1994) considered that tools and technology play an important role in the educational process. Media (books, TV, computers…) are more than passive vehicles for information: they allow active interactions that help students to assimilate new knowledge. This controversy then spread over many researchers (i.e. Koumi, 1994; Morrison, 1994; Petkovich and Tennyson, 1984).

The present study was devoted to this question: would children learn to draw more easily and more efficiently if they were taught with computerised tools? What would the advantages and disadvantages of their use be? Would using a computerised graphics tool influence children's drawing skills? Do these new digital tools enhance or reduce drawing abilities in terms of planning actions and conceptualising spatial relationships?

To answer these questions, we made an experiment designed to compare, in children, two methods for producing the same drawing: the classical 'pen and paper' method and a computerised method. Objectively quantifying the 'quality' of a drawing is a very difficult issue, even the technical quality, if the subjects of the drawings are different. This is why, instead of requiring the children to do a freehand drawing, we asked them to copy the same model. The advantage was that, since they all drew the same thing, it was easier to compare the final result. Furthermore, for the same practical reasons, we asked them to reproduce a geometrical figure which is less influenced by undesirable cognitive and affective aspects linked to a child's personality (such as drawing a little man for instance). In addition, drawing a geometrical figure allows us to assess the graphomotor and visuospatial capacities, visuomotor control, attention and working memory. Finally, we thought it was wise to use a drawing which could be quoted with a standard quotation system for facilitating the data analysis.

For all these reasons, we chose the Rey-Osterrieth Complex Figure (ROCF) (Rey, 1941; Osterrieth, 1944, Rey & Osterrieth, 1993). This test is now internationally used and it has become a common component of neuropsychological batteries, used by almost two-thirds of neuropsychologists (Knight, Kapland, & Ireland, 2003). Its reliability has been checked (e.g. Woodrome & fastenau, 2005) and scores have been shown to be consistent between test administrations. The test consists of reproducing a geometric figure with no concrete meaning (fig. 1). The ROCF is commonly used in neuropsychology to assess visuospatial construction abilities and perceptual organisation in children and adults. It consists of two test conditions: 'Copy' and 'Delayed Recall'. In the typical test, the delayed recall is used to assess the child's visual memory. In the present experiment, it was used to check whether the figure was identically memorised when it had been copied on paper and on computer.

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Figure 1: The Rey-Osterrieth Complex Figure (ROCF). The 18 items are marked on the figure.

More generally, the ROCF reflects cognitive processes regarding strategies and organisational approach at the time of drawing the figure. Typically, subjects are shown the figure and asked to copy it as accurately as they can within 3 minutes. In this copy condition, the figure is in full view. Then, after a variable delay, subjects are asked to recall as much of the figure as they can from memory. We asked two groups of children to draw the ROCF. The first group drew it with a pen on a sheet of paper ('paper' group) and the second on a computer screen with design software ('computer' group). We wanted to be sure that the possible differences in the drawings produced were due to the drawing methods and not to the children constituting the two groups. It was thus crucial to ensure that the two groups were as similar as possible with regard to the children in them. We thus evaluated the initial level of each child in several domains (graphic level, cognitive and sensory-motor development, perceptual capacities, handedness...) with a series of psychomotor and neuropsychological tests. The experiment was in two steps: the first was devoted to the tests necessary for making up the two groups and the second was the drawing test per se.

# Methods

## Participants

Twenty eight children, 14 girls and 14 boys, with an average age of 10:6 years old (range: 9 to 12 years old) participated in the experiment. They were all 4th and 5th grade pupils in a primary school. They had never used design software before the experiment but they were all used to drawing with pencil and paper.

## Procedure

### *Pre-tests*

In order to evaluate their initial level of visuospatial and graphical ability, and their perceptual-motor development, all the children were first subjected to a series of pre-tests. We used sub-components from the NEPSY (Korkman, Kirk, & Kemp, 1998; Brooks, Sherman & Strauss, 2009) and WISK (Wechsler, 1996; Sattler & Dumont, 2004) batteries which are classical neuropsychological tests. We used four non linguistic sub-tests: three (arrows, visuomotor precision, route finding) were extracted from the NEPSY and one (symbols search) from the WISC battery. We chose these sub-tests because they are made for assessing the ability to judge position and direction and the visuomotor abilities. Visuospatial and visuomotor abilities are vital in drawing.
* The 'Arrows' sub-test requires judgement of line orientation. The child looks at an array of arrows arranged around a target and indicates the arrow(s) that point(s) to the centre of the target.

* The 'visuomotor precision' test requires following as quickly as possible with a pen a path drawn on a sheet of paper, without touching the border lines and without rotating the paper. This task requires good hand motor control.
* The ‘route finding’ sub-test is designed to assess knowledge of visual spatial relationships and directionality, as well as the ability to use this knowledge to transfer a route from a simple schematic map to a more complex one. The child is shown a schematic map with a target house and asked to find that house in a larger map with other houses and streets.
* The ‘Symbol Search’ test consists of deciding if target symbols appear in a row of symbols and marking 'yes' or 'no' accordingly. The children have two minutes to give the maximum number of responses.
In addition, manual laterality was assessed using a simplified version of the Edinburgh Handedness Inventory (Oldfield, 1971).
Each child was attributed a score in the four pre-tests. On the basis of all the pre-tests, we divided the 28 children into two groups of 14 children which were also matched as closely as possible in terms of age, gender and handedness. When the two groups were as equal as possible for all the criteria, one group was allocated the ‘computer’ and the other the ‘paper’drawing.

### *Computer Drawing*

We did not want the computer drawing to differ too much from the paper drawing as regards the motor component of the task. That is why, instead of using a mouse the children were equipped with a pen tablet (Wacom intuos 2) and a pen. The children were seated at a table, in front of a computer screen. The model (ROCF) was presented on a piece of paper (21 x 29.5 cm) placed at the side of the computer screen.
“Adobe Flash Player” was used because its graphic simplicity makes it easy for 10 year-old children to use. On the screen, a white surface, representing the sheet of paper, was shown. Both drawing surfaces, paper and digital, were of identical size. Children had to look at the model on the paper and copy it on the screen. No constraints were imposed regarding the order of the strokes. When the child drew a wrong stroke, he/she could cancel it using an eraser. We did not use the animation tools which are available in “Flash Player” but we restricted its use to the graphic tools. Children were allowed to use the ready-made shapes (square,

rectangle, circle and ellipse) and the basic 'stroke' tools. For strokes and free form drawing, they could use the 'pencil' tool which is quite similar to a real pencil. They then had the possibility to straighten or to reshape the forms in order to get precise geometrical forms from the previous rough ones. For directly drawing perfect straight and curved lines or geometrical forms, they could use the 'plume' tool and the 'ellipse' or 'rectangle' tools respectively. In order to avoid favouring the 'computer' group, the practice was very short. Individual periods of 5 minutes were dedicated to the description by the experimenter of the various possibilities of the software. The child was asked to observe and to identify every icon associated with the drawing tools which were available.

Children were tested individually. The instruction was simply to copy the figure which was on the paper. They had exactly 3 minutes to do it. Immediately after that, they were asked to reproduce the same figure from memory as completely as possible.

### *Paper drawing*

The children were seated at a table with a blank sheet of paper (21 x 29.5 cm) in front of them. The model (ROCF) was presented on a sheet of paper (21 x 29.5 cm) placed at their side. Children had to look at the model and copy it onto the blank paper. No constraints were imposed regarding the size of the figure and the order of the strokes. The children were given a ruler and an eraser and they were encouraged to use them when necessary. This procedure was different from the standard ROCF procedure in which ruler and eraser were not allowed. However, since our aim was to compare with software in which these tools were included, it was important to make them available to the ‘paper’ group. Immediately after the 3 minute copy, the experimenter gave the children a new sheet of blank paper and asked them to draw the figure from memory as completely as possible.

## Results

We used the standard scoring system which assesses the copy and recall performance on 18 elements where scores can be given, ranging from 0.5 to 2.0 points (see figure 1). Two points are given if the element is correct and positioned properly; one point is given if the element is distorted or altered but placed correctly, or if it is correct but poorly placed; 1/2 a point is given if the element is distorted and poorly placed; finally, no points are awarded if the element is missing. Thus, the highest possible score is 36.

The overall results of the analysis are given in figure 2. The scores obtained by all the children in the 'copy' and 'memory' designs were submitted to a two (design mode: computer vs. paper) by two ('model': copy vs. memory) ANOVA, with repeated measures. When necessary, HSD Tukey test was used for post-hoc comparisons.

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Figure 2: ROCF scores under the two drawing conditions ('copy' and 'memory') and in both groups ('paper' and 'computer').

### Computer vs. paper

The analysis showed that the scores were higher for children who used the computer than for those who used the paper (16.8 vs. 11.0 respectively) and the difference was very close to the statistical threshold ($F(1, 26) = 4.11$, $p< 0.053$).

### Copy vs. memory

The mean scores in the 'copy' situation were higher than those in the 'memory' situation ($F(1, 26) = 96.5$, $p < 0.001$). As a whole, when the model was present, the scores were higher (15.2) than when it was absent (12.6). However, the decrease in the 'memory' situation was not the same with both design methods: the 'method' by 'model' interaction was significant ($F(1, 26) = 136.7$, $p < 0.001$). As can be seen in fig. 2, only the scores in the 'computer' group decreased under the 'memory' condition ($p<0.001$), whereas they were unchanged in the 'paper' group. The post-hoc tests also showed that the score of the 'computer' was higher than that of the 'paper' group in the ‘copy’ condition ($p<0.05$) but not in the 'memory' situation in which the two groups did not give rise to different scores.

## Discussion

As a whole, the ROCF reproductions made by the children who used the computer were closer to the model than those which were made with paper and pencil. However, this was only true in the first phase, when the children were copying the figure. In the recall phase, when they had to reproduce it from memory, both groups drew comparable figures.

### Computer vs. paper

There are several reasons why copying was less complete with pen and paper: Firstly, drawing with a pencil is more difficult and thus slower. As it is usual in the classical ROCF test, we used a procedure in which time was limited to 3 minutes and this could have placed the more difficult drawing method, namely the paper/pencil, at a disadvantage. If we had chosen to give more time for drawing the figure, we would perhaps have observed comparable performances in both methods.

Why might the 'paper' group task have been more difficult? Because 10 year-old children do not possess perfectly fine-tuned hand motor control allowing them to draw the straight lines, square and rectangle constituting this geometrical figure. Drawing the main square of the figure is not so easy with a pencil: one should decide where to begin, foresee the final size of the square, and then draw four lines connected by four right angles. Once drawn, the square is final. Of course, it is still possible to erase it, but this is time consuming. As a consequence, children hesitate more before starting to draw the figure elements and that could explain why the figures made with pencil/paper were often less complete.

Why would the task of the computer group have been easier? With the available tools for line drawing or the geometrical shapes library, it is easy for children to draw straight lines and squares with exact right angles or perfectly round circles. In addition, if it occurred that something was not correct, the 'undo' procedure allowed instantaneous erasing without too much loss of time. Finally, children probably hesitated less when beginning their drawing because they could easily start from a given shape (a square for instance...), and either erase it, if it was not suitable, or update it. This artefactual environment helped them to anticipate and thus facilitated their work. Thanks to this device, which allowed them to reach their goal step by step, the children were able to manage their learning, even if some of the underlying concepts were only partially understood (Hoyles, Sutherland & Noss, 1990 ; Noss, 1985).

## Copy vs. memory

In the classical ROCF test, the figure production from memory is usually less complete than the copy of the figure (e.g. Poulton & Moffit, 1995). Interestingly, in the present experiment, this was not the case in the 'paper' group whose performance was not statistically different in immediate copy and delayed production. Usually, the time delay between copy and recall is within the range of 5 to 10 min. and this delay is often filled by another task (e.g. Poulton & Moffit, 1995). This additional task most likely increases forgetfulness. Here we had a very short (less than 1 min.) and empty interval and thus recall was very easy. This might explain why the performance did not change in the 'memory' situation in the 'paper' group.

Performance did decrease in the 'computer' group, however. Such a difference between both drawing methods suggests that the mental representation of the figure was less detailed in the children who first copied it with the computer. Several reasons might explain the loss of quality of the recalled figure. Firstly, during the 'copy' phase, children in the 'computer' group had to implicitly learn how to use the new drawing tool. They were in a situation of implicit learning and they were probably memorising the technical procedures they were discovering rather than the figure they were drawing. Thus, they had more to learn in the same amount of time and this greater cognitive load is known to make the processing of information in working memory more difficult (Sweller, 1988; Sweller, van Merriënboer, and Paas, 1998). Secondly, the hand movements achieved by the 'computer' children were quite different from those who used the pencil. The last ones actually traced the figure and they made a movement which was as close as possible to the figure. They built a mental representation of the figure which included both a visual and a motor component. This representation is most likely richer than that created by the 'computer' children. As a matter of fact, in this latter group, the hand movements made by the children while drawing the figure were not closely linked to its form. Consequently, the 'computer' children could not refer to this sensory-motor memory when they had to recall the form of the figure. This is very close to what has been observed when handwriting and typewriting have been compared. Visually recognising newly learned characters was easier when they had been learnt by handwriting than by typewriting (Longcamp et al., 2005; 2006). Furthermore, the brain areas involved during the visual presentation of the characters differed according to how they had been learnt previously (Longcamp et al., 2008).

According to Schön (1983), the hand movements achieved during drawing should be accompanied by a verbalisation to be really efficient. Drawing by hand would induce a "reflection-in-action” (Schön, 1983; Schön & Wiggins, 1992) that is a thought during the realisation, an on-line dialogue between the designer and the drawing in progress. With CAD, this dialogue is supposed to be less restrictive. Finally, as discussed previously, 'paper' children probably spent more time visually scanning the figure before starting to copy. This might favour creating a richer mental representation in which more details were included. This might explain the strange fact that, for several children, strokes were drawn in the 'memory' condition whereas they had not been drawn in the preceding 'copy' condition. Obviously, this observation cannot be accounted for by motor memory.

## Conclusion

These preliminary results suggest that using a CAD tool could help children while they copy a model, but that it does not improve their ability to draw the same figure using their own, internal model. However, this pilot study suffers from several limitations that have to be overcome in the future. In particular, the time spent in using the CAD tool was obviously too short for giving the children the possibility to use it efficiently. Obviously, a lot of practice is necessary. Furthermore, monitoring what children actually do while drawing, both with the computer and with the paper, is essential. This is necessary for knowing which procedures they use with CAD, in what order they draw the strokes, and so on... This is also important in paper drawing (Olsen, 1992). The children's age is another point that should be questioned. Younger children, who are less used to drawing and whose hand motor control is less developed, should also be tested. Finally, for practical reasons, we decided to ask the children to copy a geometrical figure, a procedure that prevents study creativity, a relevant aspect of drawing. It would be interesting to improve the artistic content of the drawing to try to ascertain whether the new drawing technologies have a positive or negative impact on the user's creativity.

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Figure 1: The Rey-Osterrieth Complex Figure (ROCF). The 18 items are marked on the figure.

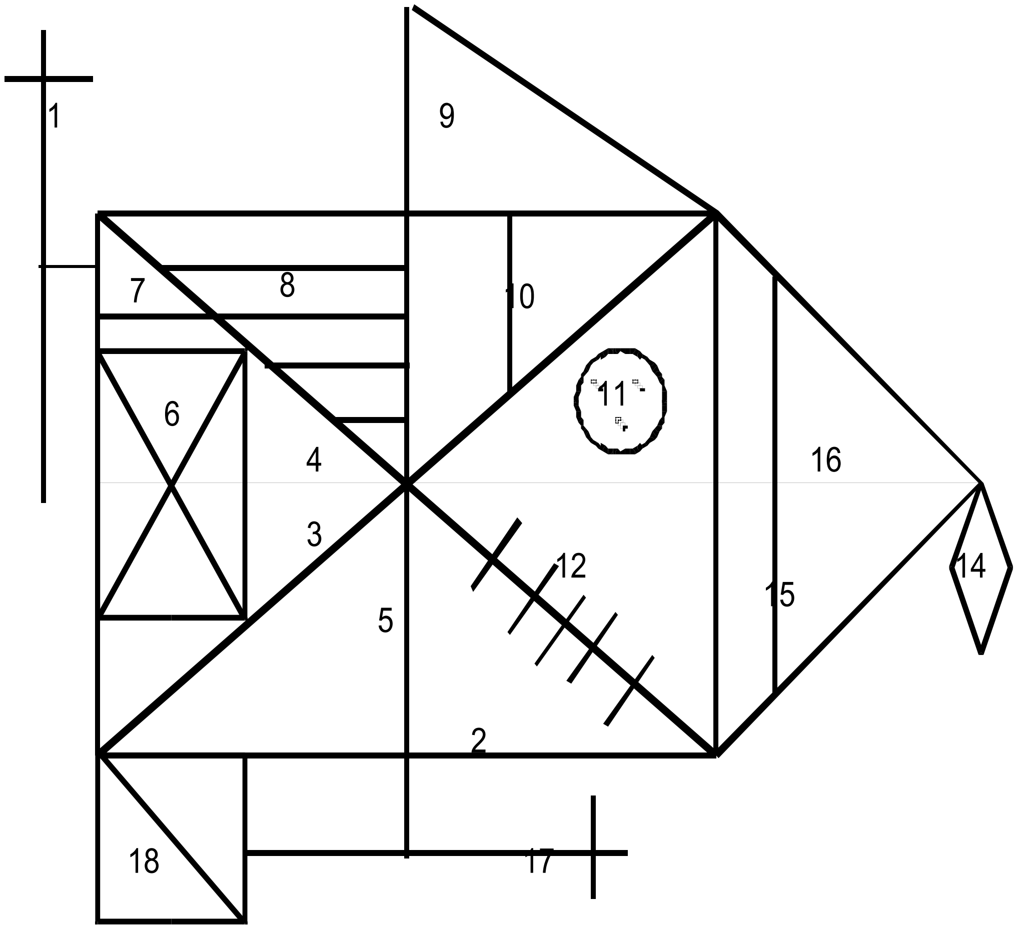

Figure 2: ROCF scores under the two drawing conditions ('copy' and 'memory') and in both groups ('paper' and 'computer').