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Does regularity affect the construction and memory of a mental image in the same way it affects a visual trace?

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It has been shown that regularity of a figure aids both its perception and its retention. The present paper examines how the regularity of a pattern may influence memory of figures contrasted with generated images and how specific configurations can affect memory. It is assumed that a visual trace and a generated image imply partially different psychological mechanisms and that memory of a generated image is affected by the way it was constructed. In four experiments different groups of subjects were invited to draw simple figures on the basis of the memory either of its pictorial presentation (VT = visual trace) or of the corresponding image generated following verbal instructions (GI = generated image).
Experiment 1 showed that a VT condition generally produces poorer memory than a GI condition, but this difference only occurs with some figures. Experiment 2 showed that difficulties and peculiarities in the GI condition are due to the extent to which a subject can find partial elements of regularities during the construction of a figure. This result was not present in a CVT (constructed visual trace) condition progressively showing the segments of a figure (Exp. 3) and was present, but to a lesser extent than in the GI condition, when single segments were presented to the subject, who was required to imagine the overall resulting pattern (Exp. 4).

Key words: Perception, representation, visual memory.

The present paper develops the hypothesis that a generated visual image can only partially be assimilable to an analogical representation derived from visual experience (a visual trace). In a series of studies, this hypothesis was tested with reference to the effect resulting from the regularity of patterns which had to be remembered either after visual presentation or imaging.

During the 1970s and 1980s, as a result of controversies between propositional and analogical positions about the nature of mental images, many experiments were done to shed light on the strong connection, and in some cases the sharing of processes as well, between imagery and perception. Some of this research has shown that figurative gestalt properties were active in both cases. For example, Thompson & Klatzky (1978) showed their subjects some outlined geometric figures that were complete or split into two or three parts. The subjects had to synthesize the parts mentally into a unitary figure which they then compared to a figure successively presented. If the synthesized figure was a well-organized one, the reaction times were constant as the number of components increased, whereas if the synthesized figure was poorly organized, the reaction times increased as the number of components increased. Thus, these results suggest that the well-organized and mentally built figures were unaffected by increases in complexity, whereas the poorly organized mentally built figures required more time as the complexity increased. Murphy & Hutchinson (1982) asked their subjects for a mental construction of geometric patterns on a 4 by 4 matrix (16 cells) which was placed in front of them during the course of the experiment. The subjects built up the mental patterns on the basis of a verbal description where every cell of the grid was defined as "empty", "full", or "half full". Then, the subjects had to draw the patterns which they had previously mentally constructed. A control group of subjects observed the already constructed patterns and, later, drew the patterns. The results, as well as other differences, showed that performance decreased when the symmetry or goodness of a figure declined or when the complexity of the figure increased. Saariluoma & Sajaniemi (1989) demonstrated that when the visual information was structured in chunks because of the presence of perceivable regularities, memory load was reduced. Extending these results to imagery tasks, Saariluoma (1992) showed that the construction of mental images was easier if these images had a "good" shape. He presented subjects with verbal messages that defined the cells of a matrix in which they had to locate a dot. The final dot configuration could either present a good form or be scattered. The dependent variable was the number of dots correctly placed. This number was greater for good forms than for scattered ones.

The common aim of the study was to demonstrate that "gestalt properties" contribute to both imagery and perception. Reed (1974) studied the effects of such properties on visual memory. In his experiments, subjects who had previously memorized visual patterns were presented with figure tests which could either be, or not be, subparts of those patterns. When the subparts were bad figures they were recognised only rarely. Finke, Johnson & Shyi (1988); Glushko & Cooper (1978); Hollins (1985); Kosslyn, Reiser, Farah & Fliegel (1978); Reed (1984); and Slee (1980) carried out further research on this topic. Considering that a visual image is an analogical - rather than a literal- representation of a perceived object, data showing an effect of regularity on visual memory could be interpreted as evidence that principles of regularity influence both perception and visual imagery.

In conclusion, regularity of a shape seems to affect its immediate and intermediate memory (Goldmeier, 1982). If we assume that a regular shape is better organized into a smaller number of visual chunks, we can associate regularity and complexity by attributing the effect to a smaller memory load. However, despite the fact that it seems self-evident that a visual memory system will be limited by the number of elements in a pattern in short term retention (Logie, 1988, p. 33), the effects of regularity and complexity of patterns on memory has not been fully explored.

This may be due to the operational difficulties linked to the definitions of perceptual complexity (Attneave, 1957) and regularity or goodness (Hochberg & McAlister, 1953; Palmer 1977 [Palmer's method is not suitable in our context because of the different number of segments in his patterns]; Leeuwenberg & van der Helm, 1991), as well as to the problem of whether these distinctions can be directly applied to memory, and to the unclear relationship existing between complexity and regularity. Furthermore, if we want to manipulate complexity and/or regularity in the field of mental imagery, the issue becomes more complicated, since a mental image can be of a different nature, and, in particular, can exactly correspond to a recent visual trace or be the product of more complex generating processes. In the present paper, we intend to develop this line of research through consideration of the effects of regularity and complexity in memory. We will assume a point of view which is partially different from research looking for analogies between mental imagery and perceptual activity. In fact, we think that a generated visual image may differ from a visual trace. This difference also affects the way in which the gestalt properties are processed and used. The purpose of our research is to discover and describe these differences.

Mental images can originate from different sources. Therefore, they may differ according to the information and processes that generate them. In the present paper, we will take into consideration: 1) directly observed mental images constituted from short term memory of configurations. We will call them "Visual Traces" (VT); 2) mental images constructed from verbal instructions or "Generated Images" (GI). Visual Traces result from low level processes, directly from perception. Generated Images result from higher level processes, including the comprehension of instructions, production of figurative elements, and synthesis into a unitary pattern. We (Cornoldi, De Beni, Giusberti & Massironi (1997); Giusberti, De Beni, Cornoldi & Massironi, 1992; Rocchi, Cornoldi & Massironi, 1992) found that VT and GI differ in various ways. One way in which they differ is that the construction of a representation is immediate and holistic in the case of a visual trace, while it is sequential in the case of a generated image. Other differences concern the "pop out" of properties of the stimulus, sensitivity to physical resemblance (these two effects are mainly present in a VT, Giusberti et al., 1992), the sensitivity to conceptual information, and age (effects which mainly influence a GI). The differences that we observed are part of a broader field (for a review, see Intons-Peterson & McDaniel, 1990), which shows that even though generated images share elements with other forms of representation based upon language, concepts, etc., they are not perfectly analogical with the visual perception. Therefore, it seems evident that former studies on the analogy perception-imagery should be reconsidered in order to find a more analytic description of the relationship between the two processes.

With the purpose of exploring the distinction between visual traces and generated images, we chose a paradigm based on the visual exposure to a configuration (VT conditions), or on the mental construction of the configuration (GI conditions). In both cases the subjects were then asked to draw the configuration from memory. Within GI conditions, subjects were asked to imagine a 2 by 2 square shaped grid, made up of 4 small squares and/or a figure made of 12 segments. The subjects were asked to mentally build the figure using the consecutive segments verbally given by the experimenter. Within VT conditions the subjects could immediately see the whole configuration. Immediately after seeing the figure, or after a short interpolated phase, the subjects from both groups were asked to draw the figure on the basis of their memory.

The partially different processes required either for the generation of a mental image or for loading a visual trace could imply different effects on memory. Within the GI condition, processes of sequential construction, of representation, of maintenance of the image, and, finally, processes of drawing the configuration were activated: therefore, potential problems during one or more of these phases could cause a subject to perform badly in the GI condition. On the other hand, in the VT condition, poor performance might be due to observation, maintenance, or drawing of the configuration. Since we did not have any evidence of the optimal conditions for carrying out this task, or a good criterion to define the regularities of the stimulus, we had to find different ways of probing the effects of variables likely to be implicated in our experiment. We chose a basic condition, simpler than that of Murphy and Hutchinson (1982), and similar to Palmer's (1977), because the simpler configuration restricted the number of critical elements, and so presented a less heavy initial memory load for our subjects. Keeping the same level of complexity (defined by the number of constitutive segments), in a first study we considered the subjective experience of difficulty that each configuration caused, in order to analyse how much it influenced the memory of the visual trace and the memory of the generated image. In subsequent experiments, principles of regularity were defined not only on the basis of the final result of the configuration, but also on the basis of the phases involved in the construction of the image. Finally, we examined whether the sequential construction of the perceived visual configuration could have similar effects to those detected when studying a generated image.

The whole set of experiments was designed to study whether or not principles of regularity influence a GI, and whether this happens in a similar way for a VT. In agreement with our previous observations about the relationship between VTs and GIs, we hypothesized that a GI, despite its differences from a VT, could have quite different properties from a simple propositional representation that generally would not be influenced by elements of regularity related to the described figure. Therefore, we hypothesized that the GI was susceptible to aspects of regularity (as was the VT), but that these aspects were not identical. In particular, memory for visual traces would be helped by the overall stimulus properties more than memory for generated images. On the contrary, specific aspects of regularity emerging during the construction of the generated image could be particularly critical in affecting the memory of the image. These specific aspects could be better evidenced by considering the specific mental implications of every single pattern and the way in which it was constructed. In fact, while in the basic VT condition the subject's performance could be influenced only by the figural complexity/difficulty defined a priori, in the GI condition the subjects' performances could also be influenced by the kind of description given to them; in fact, figures with the same figural complexity could become harder or easier by modifying the way they are generated following verbal descriptions: descriptions which facilitate the emergence of regularities during the construction of an image could help memory of it.

The first Experiment of the present research tested the hypothesis that a VT produces quantitative and qualitative memory which is different from that of a GI. Memory reproduction of figures was tested after a short visual exposure to a large variety of 8-segment figures and after the construction of the corresponding mental images. Instructions for the construction of mental images were arranged so that the emergence of possible regular chunks during the image construction was minimized, thus making the subjects rely on the regularities emerging as the whole pattern was generated. In a second Experiment, we selected, on the basis of the results of Experiment 1, the stimuli which were most appropriate for a comparison between a VT and a GI, and we contrasted the GI condition administered in Experiment 1(difficult-GI) with a condition facilitating the formation of chunks during the process of construction of the image (easy-GI) and with the standard VT condition. In a third and fourth Experiments, we examined whether differences in the two orders of presentation of segments, involved in the difficult-GI and easy-GI conditions, were also present in conditions which were more linked to the VT condition. In fact, in Experiment 3, subjects were exposed to the construction of the figure, where -with different orders- each segment was separately presented and added to the already formed pattern. In Experiment 4, again, each segment was perceptually presented, but the preceding part of the figure was no longer perceivable, so that only one segment at a time was visible, and the subject had to use mental imagery in order to create the representation of the overall figure.

EXPERIMENT 1

The first Experiment tested the hypothesis that a visual trace produces quantitative and qualitative memory which is different from that produced by a generated image. We assumed that, despite the fact that the memory of a GI is also facilitated by its regularity, when its elements of regularity are reduced to the final configuration assumed by the generated image, the facilitation is less evident with respect to the case of a visual trace whose regularity is immediately evident. Memory for a VT should, therefore, be better than memory for a GI. Furthermore, we assumed that great differences could be found, both in absolute values and with reference to the contrast between a VT and a GI, for different figures. In fact, each figure possesses specific properties of subjective regularity and complexity.

In order to discover the stimuli representing all the different types of figures within a well defined set of stimuli, we conducted a pilot study in which a large sample of 54 8-segment patterns were shown to the subjects in order to obtain a measure of the degree of the subjective difficulty in memorizing related to the various stimuli. Considering the task of the present experiment, we focused on the subjective impression of difficulty for memory that people may have when looking at a pattern. This aspect seemed to be influenced by the elements of regularity and complexity, which were presented in the whole configuration and which should be detected particularly in a VT condition. However, the pilot study showed that subjects encountered fewer problems in rating the subjective difficulty of the figures than their complexity or regularity.

The 54 8-segment patterns drawn represented all the possible patterns which could be generated, when minor replications and mirrored patterns were eliminated.

In the pilot-study we asked 10 young adults to rate, on a 10 point scale, the subjective difficulty of the patterns (10=maximum of difficulty; 1=minimum of the difficulty). A difficult pattern was defined as a pattern which appears to create difficulties when it has to be analyzed/scanned and then reproduced from memory.

METHOD

Subjects. 32 students from the University of Verona (16 males and 16 females) were randomly assigned to two groups (GI and VT).

Material and procedure. On the basis of the mean difficulty ratings obtained in the pilot-study, we selected eighteen 8-segment patterns from the pool of 54 stimuli: six with low ratings of difficulty, six with intermediate values, and six with high values of difficulty. The range of mean difficulty ratings was between 1 and 8.6; the group of stimuli with low difficulty values had a mean score of 1.63 (range between 1 and 2.2); the group of stimuli with intermediate difficulty values had a mean score of 3.85 (range between 3 and 5); the group of stimuli with high difficulty values had a mean score of 7.9 (range between 7.2 and 8.6).

The visual trace group (VT) was presented each pattern, without the grid, for 5 seconds and, after a 20 second interpolated task (identical to the GI condition), were required to draw the pattern on a blank grid. Before the instructions, subjects in the GI group were exposed to the blank grid, which was immediately removed, and were then asked to close their eyes and generate a visual image by following a description of the pattern, based on the presentation of one segment at a 3-sec rate. The segments were consecutive and the subjects knew that the description always started from the top left vertex of the grid. Furthermore, when possible, the instructions presented segments one after the other, which were not along the same line.

At the end of the sequence there was an interpolated task in which subjects had to count backwards by seven starting from a four-digit number for 20 sec. The presentation order of the patterns was randomized for each subject. For each group, the experimental session was preceded by two practice trials.

RESULTS

We computed the mean numbers of the correctly reproduced segments for each pattern in the two groups. The mean numbers of correct reproductions were, for the VT modality, 7.97 for the low difficulty, 7.05 for the intermediate difficulty, and 6.01 for the high difficulty; for the GI modality the mean numbers were 7.41, 5.97, 5,3 for low, intermediate and high difficulty respectively. We then performed a 2 (groups: VT and GI) X 3 (levels of difficulty: easy, medium, difficult) X 6 (stimuli) ANOVA with a mixed design. All 3 main effects turned out to be significant: groups $F(1,30)=8.55$, $p<0.007$; levels of difficulty $F(2,60) = 72,34$, $p<0.0001$; stimuli $F(5,150) = 4.59$, $p = 0.0006$. Two interactions also turned out to be significant: levels of difficulty X stimuli $F(10,300) = 2.53$ $p<0.007$; groups X levels of difficulty X stimuli $F(10,300) = 2,37$ $p<0.02$.

The meaning of these results can be summarised as follows:

The VT group performed better than the GI group.

The post hoc Duncan's test (_=0.05) showed that easy stimuli allowed better recall than the medium and difficult ones, which also differed significantly.

It does not make sense to interpret the third main effect since stimuli in the three levels of difficulty were not paired.

In order to provide clarification, for each of the three difficulty levels of the patterns a two way ANOVA was calculated: Groups (2 levels, GI and VT) by Stimuli (3 levels).

The results showed that in the first two levels of difficulty:

1) the subjects in the VT group made more significantly precise reproductions of stimuli than the subjects in the GI group;

2) there was a significant effect of stimulus type, as the number of mistakes depended on the kind of stimulus, but the pattern of results was similar for both groups (VT and GI).

The analysis based on the category of "difficult" stimuli gave different results as the interaction yielded significant results $F(5.150)=2.56$, $p<0.003$. This shows that in this specific case, the characteristics of the stimuli do not influence the performance of the two groups (VT and GI) of subjects.

Re-examining stimuli and instructions given to the subjects of the GI group, we noticed that, for some patterns, memory of a generated image could be facilitated by the particular order of the segments proposed in the instructions. This happened particularly in relation to stimuli rated as particularly difficult, which are perceptually more unstable since they do not get automatically organized into 2 or 3 under-units that are simple and well structured (chunks). This characteristic can cause difficulty in the maintenance of a visual trace. On the contrary, the process of GI construction, based on the instructions given, can make a hard figure much less difficult than other ones. Indeed, the sequence of the instructions can produce some facilitating indications such as:

1) the alternative repetition of the very same two instructions (low vertical, right high diagonal, low vertical, high right diagonal);

2) the repetition of the very same instruction to describe two adjacent segments (low vertical, low vertical);

3) the request to form a right angle (low right diagonal, high right diagonal).

Therefore, the sequence of instructions can help the GI group when the patterns are irregular and complex.

DISCUSSION

The main purpose of this experiment was to examine, within a pool of stimuli that were homogeneous for number of segments and heterogeneous in other respects (as described by a general index like difficulty rating), the different implications of a visual trace and a generated image condition. We found that a visual trace condition produced a higher performance than a generated image condition and that this difference varied according to the particular characteristics of the selected stimuli.

The judged difficulty of the stimuli used in this experiment was determined by the subjects of the pilot-experiment, on the basis of a metacognitive evaluation of their memorability. However, this evaluation came from the direct observation of all different patterns. Therefore, the values on which memorability was estimated could be related to the VT condition, but could only be useful by extrapolation in determining the performance of the GI group. This was particularly true if we hypothesized that the two modalities had different ways of processing data. In the VT group, the differences between stimuli were exclusively related to their visual characteristics. In the GI group, the differences among stimuli depended on the following two factors:

1) the visual characteristics of the figure;

2) the kind of description that was given to the subjects, that is, the way in which the sequence of instructions was structured.

Some of the configurations used in the experiment could have been described by more than a single sequence of directions. Among these sequences, some of them could make it easier to complete the mental construction, while others could make it more complicated. For example, some of the descriptions that make it easier to build the configuration are those that list, one after the other, the sequences of segments that fall along the same line. In contrast, anytime this "continuity of direction" of the sequence is broken, it is much harder to mentally generate the image and to remember it.

The results obtained more particularly with the hard-to-remember stimuli (difficult stimuli) lead us to the hypothesis that there could be some patterns whose GI condition allows the subjects to perform better than in a VT condition. We believe that this happens when we use complex (and perceptually unstable) configurations that cannot be organized at a fast rate of presentation. In this condition, a sequence of directions which suggests the presence of organized components, and that leads the construction of the image along a facilitating sequence of segments, can facilitate the task, making the configuration more stable. The result is a better memorized generated mental image.

EXPERIMENT 2

The task required of the subjects in the GI groups in the preceding experiment was based on at least three main phases: the construction, the conservation, and the reproduction of the pattern. Any of these phases could in principle have contributed to the lower memory performances of GI as compared to VT groups. In former research, regularity was only analyzed in relation to the final appearance of the configuration. In contrast, in our present experiment, we tested whether the sequence of segments or the possibility of having a "chunk" as early as possible during the construction of the image could influence its reproduction.

The main purpose of this experiment was to verify whether, in the GI condition, the degree of difficulty in constructing the mental image depended on the order in which the subjects were given the instructions, which were always the same. Therefore, we used stimuli that could be organized into at least two sequences, one "easy" and the other "difficult". In the case of an "easy" sequence, two segments, sequential on the same line, were always mentioned in succession. In the "difficult" sequence, continuity among segments was always avoided.

We also predicted that the subjects of the VT group would answer more correctly than the subjects of the GI group who had more difficult directions (hard sequence: GI-difficult), but not more than the GI subjects who had the easier directions (easy sequence: GI-easy). As the most critical difference between VT and GI in Exp. 1 concerned the group of difficult stimuli, in this Experiment we focused on that group of stimuli. However, we expected that, as in Experiment 1, specific differences could be found between stimuli. Stimuli whose complete overall configuration offered elements of regularity would have advantages over the VT condition. On the contrary, stimuli constructed following instructions stressing the partial elements of regularity emerging during construction (GI-easy condition) could be facilitated in the case of a GI.

METHOD

Subjects. Forty-eight subjects (24 males and 24 females) took part in the experiment. The subjects were students from the University of Verona and they were randomly divided into three groups: GI easy, GI hard and VT.

Material and procedure. The experiment was based on 12 stimuli constructed into the usual 2 by 2 square grids. They all belonged to the group of the "difficult" figures in the pilot study. All patterns were asymmetrical figures and they all had at least a couple of segments which were sequential on a continuous line. More precisely, one pattern had just one pair of sequential segments, eight of the patterns had two pairs of sequential segments, and three patterns had three pairs of sequential segments (see figure 1).

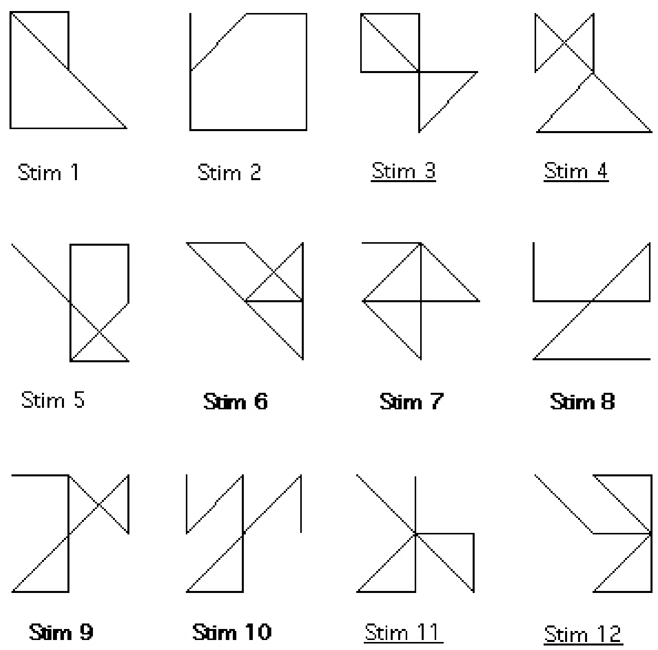

Figure 1. Stimuli used in experiment 2.

All stimuli had two sequences of instructions, one "easy", where adjacent segments were listed one after the other, and one "difficult", where adjacent segments were not listed sequentially. For example, the third stimulus was described in the following way:- EASY = Right horizontal, vertical down, vertical down, up-right diagonal, left horizontal, left horizontal, up-vertical, low-right diagonal.

HARD = vertical down, right horizontal, vertical down, up-right diagonal, left horizontal, up-left diagonal, right horizontal, down vertical.

The procedure was the same as in the experiment 1.

RESULTS AND DISCUSSION

We calculated the number of segments that were correctly reproduced by each subject for each stimulus. We considered every segment exceeding number eight to be an error. This kind of error occurred in 41 cases out of 576 answers, and primarily in the VT group (26 cases out of 192 answers).

In a first analysis of variance based on Groups (3 levels, GI easy, GI difficult, and VT) by Stimuli (12 levels), the main effect of groups was significant, $F(2,45) = 4.8$ and $p<0.02$; the post hoc analysis (Test of Duncan, $p<0.05$) revealed that the GI difficult group ($x=5.76$) had a significantly lower number of correct answers than the GI easy group ($x=6.51$), and than the VT group ($X=6.33$), while the performances of the latter two groups did not differ. This result shows that a stimulus could induce the subjects to make a different number of mistakes, according to the kind of description of the stimulus given to them. The main effect of the stimuli was also significant, $F(11,495)=5.34$ and $p<0.0001$; the post hoc analysis (Test of Duncan, $p<0,05$) revealed that stimulus 1 produced fewer errors (correct answers $x=7.29$) than the others, and that it was significantly different from all the other stimuli except 2 and 8. By contrast, stimulus 5 had the lowest number of correct answers, and it differed significantly from all the other stimuli except 6 and 7.

The interaction Groups X Stimuli was also significant $F(22,495)=2.73$, $p<0.001$. Simple effects analysis showed that the stimuli in which we obtained a significant difference between groups, were 2,4,7,9,11,12 (half of all the stimuli). The interaction was due to the fact that for stimuli 1,3,4,11,12, most of the correct answers were in the VT group, while for stimuli 2,6, 7, 9, 10, memory was better in the GI easy group. Comparing groups by twos, namely GI easy/GI difficult, GI easy/VT, GI difficult/VT, we obtained a significant interaction between Groups X Stimuli, $F(11,330)=5.03$, $p<0.04$. In figure 2 we can see that the different sequences of instructions affected performance, and this was more evident for some figures than for others. The post hoc analysis showed differences between the two sequences of instructions that were significant for stimuli 2 ($p<0.02$); 5 ($p<0.04$); 7($p=0.02$); 9($p=0.02$) and tentatively 12 ($p<0.06$).

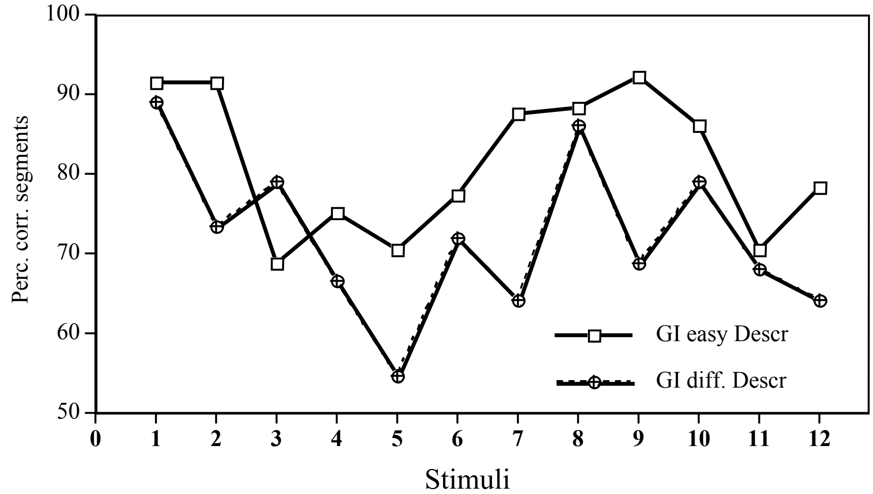

Figure 2. Mean percentages of segments correctly reproduced by subjects of the generated image with easy descriptions group (GI easy Desc) and subjects of the generated image with difficult descriptions group (GI diff. Desc), according to the twelve stimuli of experiment 2.

In order to interpret these results, it is important to follow, step by step, the construction phases of two particularly clear cases, regarding stimuli 2 and 5 and their instructions. In figure 3, the sequences of two stimuli can be seen, in which the easy sequence determined significantly better results than the difficult one. If we consider Stimulus 2, we can see that the difference in the two sequences of instructions (easy and difficult) has a dramatic effect, because the easy sequence leads the subject to build a figure that is almost completely a square (which is a very simple figure), and only the final construction is not coherent with the square. In the difficult sequence, the diagonal side appears at the very beginning, on the second instruction, and is an element of disturbance that affects all the subsequent construction of the mental image. With Stimulus 5, again we see that on the fifth instruction for the GI easy group the image is well structured in a simple pattern, as a consequence of the aligned segments; in the difficult sequence, at the fifth instruction the figure is not yet structured into something regular, and this makes it difficult to refresh the image and to add the subsequent segments.

These results are in general agreement with Saariluoma (1992) who, when speaking about the construction of mental images on the basis of verbal instructions, says that the subjects "are able to associate random dots with fragments of 'good' forms" (p.416).

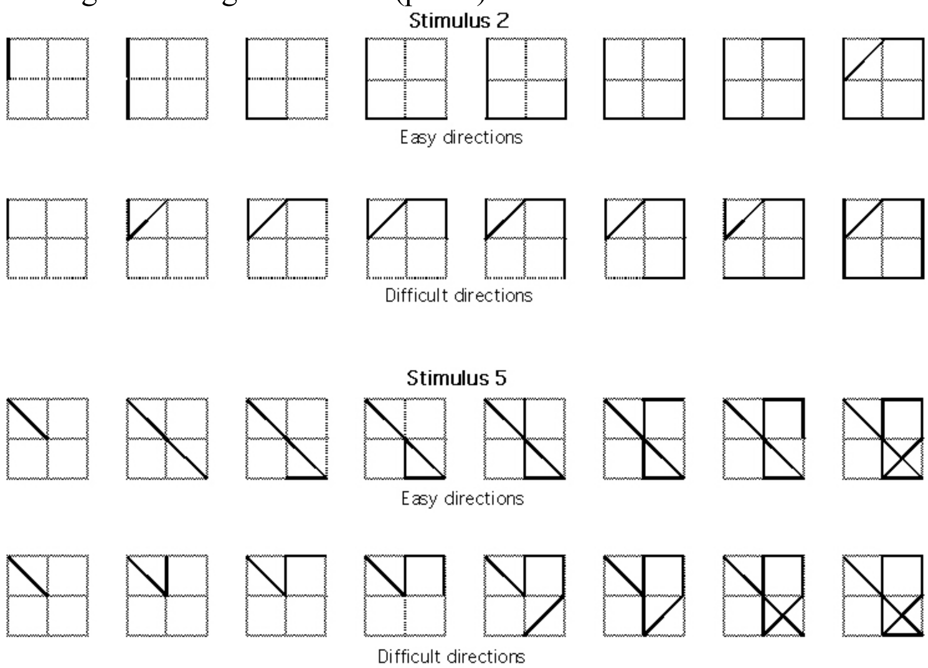

Figure 3. The sequences of the directions related to: (a) stimuli 2 and 5 in which the easy sequences determined significantly better results than the difficult ones; (b) the stimuli 4 and 8 for which the difference between easy and difficult directions was not significant.

Post hoc tests based on simple effects revealed that the significant differences ($p<0.05$) between VT and the GI-difficult were related to stimuli 2,4,11 and 12, and these all favored the VT group.

The general conclusion to be drawn from the Experiment is that patterns are memorized and reproduced better when they are acquired as visual traces than when they are mentally assembled piece by piece without the possibility of finding clear regularities during the construction of the image. However, patterns are better memorized and reproduced when they are constructed according to sequences of facilitating instructions. For some stimuli, sequences with difficult instructions, on the other hand, lead to results which do not statistically differ from those obtained under direct observation of the stimulus.

EXPERIMENT 3

The goal of experiment 3 was to investigate further the characteristics of the processes which produced the results of experiments 1 and 2. One of the most conspicuous differences between the generation of mental images on the basis of verbal instructions and the direct observation of patterns lies in the fact that, while the first case utilizes a sequential procedure which is analytic, constructive, slow, and voluntary, the second employs a holistic, organizational, rapid and involuntary process (Giusberti et al., 1992). We assume that the first procedure promotes recall of the GI over the VT provided that the pattern is perceptually complex and unstable and that the description for the creation of the GI favours the formation of chunks. The second procedure, with the immediate perceptual exposure to the whole pattern, favours the recall of salient, perceptible and stable patterns, such as "good" figures. Those who advocate a close analogy between imagery and perception contend that perceptual activity and imaginative activity lead to the same cognitive results. We believe that this is not true. In the third experiment we assumed that a VT can have different implications from a GI in the case of our stimuli, even when perceptual activity is rendered analytical and constructive.

Thus, subjects were driven to construct a VT in an analogous way to that employed in creating the GI in experiment 2. To this aim we created a new experimental condition that can be defined as "constructed visual trace" (CVT). In this condition, the stimulus is assembled, segment by segment, on the screen of a PC in front of the subject, who must subsequently reproduce the entire pattern. Each segment is presented at 300 msec intervals, an interval deemed sufficient for the subject to analyze the temporarily formed shape. Obviously, the CVT procedure allows for two "conditions" of varying difficulty (easy = the segments appear according to a principle of regularity used for the GI easy condition of the preceding experiment; difficult = the presentation sequence does not allow formation of regular shapes until the end). We assumed that, unlike in the case of a GI, in the case of a VT two different types of instructions would not produce substantial differences.

METHOD

Subjects. The 32 subjects, half males and half females, who participated in the tests were either students at the Universities of Verona and Padua or employees of various offices. All were between the ages of 19 and 38, and had earned a high school diploma. They were randomly assigned to two groups of 16.

Material. The stimuli consisted of the 12 patterns used in experiment 2. The stimuli appeared on the screen of a Macintosh LC personal computer in the following ways: - For the easy CVT Group, each of the 12 stimuli was assembled, segment by segment, on the computer screen according to the sequences set out in the description of the Easy GI group in experiment 2. The interval between successive segment appearances was 300 msec and the final form likewise appeared for 300 msec. - For the difficult CVT Group, each of the 12 stimuli was assembled, segment by segment, on the computer screen according to the sequences set out in the description of the Difficult GI Group in experiment 2. Presentation times were the same as in the easy CVT Group.

Procedures. Each subject was tested individually, seated at a table on which a Macintosh LC personal computer screen was located about 50 cm away. Prior to the experiment, all subjects were shown the answer sheet, a 2x2 grid, then subjects were told that they would see the progressive formation of shapes on the screen. They were to follow the construction of the figure and try to memorize it because, as soon as it disappeared, they would be expected to reproduce it as accurately as possible on the answer grid provided. Before beginning the actual experiment, all subjects took three practice-trials, at the end of which they were asked whether they understood what was required of them, or if they wished to take other trials. Only two of the subjects requested additional practice-trials.

RESULTS AND DISCUSSION

The number of segments correctly reproduced by the subject for each stimulus constituted the data analyzed by means of a 2x12 ANOVA. The variables under consideration were: degree of difficulty of instructions at 2 levels (easy, difficult) between subjects; -type of stimulus at 12 levels within the subjects. Only the main effect of the variable stimuli turned out to be significant, $F(11,330)= 9.43$, $p < 0.0001$, confirming that the number of correct replies depended on the figural characteristics of the stimulus.

The effect of difficulty of the sequence was not significant $F(1,30)=O.O11$, $p.=0.92$, nor was the interaction difficulty x stimuli significant $F(11,330)=1.25$, $p.= 0.25$. This result is the opposite of that obtained for the GI group in experiment 2, where the type of sequence used in the directions could either facilitate construction of the image or render it more laborious. This result suggests that, from the moment the incoming data is processed in an encapsulated manner (that is, by utilizing methods which are impervious to integration with other processes), the perceptual activity at the early levels of processing is unable to utilize the partial organization which could be constructed due to the sequence of "easy" construction. This fact appears to agree with theories which support modularity of the mind (Fodor, 1983) and indicates that the procedure of sequential construction of the stimulus, whether "easy" or "difficult," disturbs the structuring of the CVT in the same way for all the stimuli. Contrary to the case of the GIs, the construction of the stimulus in the time directly observed, at least with the appearance of a segment each 300 msec, does not allow the CVTs to form those chunks which rendered stable the GIs obtained under facilitating conditions.

The results of experiments 2 and 3 could leave room for some methodological doubts.

In experiment 2 the sequence of verbal instruction (easy/difficult) given in the GI condition required the participants to keep the 2X2 grid on which they had to build the pattern in their minds. The VT group, instead, observed the stimuli without a grid, and saw the grid only when they had to answer.

In experiment 3 there were only CVT (Constructed Visual Traces) conditions, and the participants observed the patterns while they were being built, segment by segment, over time. A new side was added to the preceding ones every 300 msec., offering the possibility of perceiving and anticipating the configurational regularities of the pattern. It is possible to suppose that the two sequences of instructions (easy and difficult) did not differ significantly, because the already presented segments were available on the screen in both cases, aided by the fact that the complete pattern was seen for 300 msec. This brought subjects to focus on the overall pattern, rather than on specific chunks of segments. In order to control these aspects we ran a further experiment.

EXPERIMENT 4

A new experiment was organized in order to control both of the main aspects mentioned in the discussion of the preceding Experiment. In this experiment the segments were presented one at a time, in isolation, removing the previous ones, but again using either an easy or a difficult sequence of directions. This procedure could be performed with or without the grid. In the former case, it could be the control condition for experiment 2, and for experiment 3 in the latter.

Some preliminary trials were run in which, in accordance with the condition of experiment 3, the time for each segment presentation was 300 msec. But after a pilot study we realized that the task was too difficult, and a floor effect was the result.

Moreover, the perceptual result on the computer screen was something like a stroboscopic effect in which a single segment was seen to jump here and there on the screen.

Even though there was no stroboscopic phenomena, a floor effect was again registered with 600 and 900 msec of presentation time. Eventually we decided on 1200 msec of presentation time for each segment. This time is closer to that applied in the GI condition in experiment 2. In fact, the verbal instructions were issued, in that case, every 3 seconds, and it can be supposed that half of this time was employed in the verbal description of the segment by the experimenter, and the other half was employed in the imagery operation of building up the pattern.

We consider this task as an operation in between VT and GI. We will call it, from now on, GIvt condition because the pattern construction is imaginative, while the load of the segments is visual. Analogies between the procedure followed in this Experiment and the procedures followed in the two preceding Experiments made it possible to make comparisons not only within this Experiment, but also across Experiments.

Regarding the comparison between the different experimental conditions, we expected a significant difference between groups with and without grid, given that the task with the grid helps the subject to locate the segments within the general configuration. Therefore, we did not expect significant differences in the comparison between the GI condition of experiment 2 and the group with grid of experiment 4, because the two tasks are really similar. On the contrary, we expected a significant difference between the CVT group of experiment 3 and the group without grid of experiment 4, because the permanence of the segments on the computer screen until the building of the complete pattern, as in experiment 3, does not require any mental construction, only observation of the event and loading of the result. In experiment 4, instead, imagery work is required, and this involves much more cognitive commitment.

Concerning the effect due to the difficulty of sequence, different predictions could be made. As we have already claimed, the task required of the participants in this experiment can be considered an intermediate case between the GI and VT conditions. The significance can, therefore, depend on the closeness of this task either to GI or to VT conditions. In the present case, we think that it is very close to the GI one and, therefore, it is more likely that differences due to the difficulty effect will turn out to be significant.

As far as the last variable, i.e. stimuli, is concerned, it was logical to expect that differences among them could turn out to be significant, as they were in the previous experiments, given their structural differences.

METHOD

Subjects. The 64 participants, half males and half females, were students from the universities of Verona; all were between the ages of 19 and 34. They were randomly assigned to four groups of 16.

Material. The stimuli consisted of the 12 patterns used in experiment 2, but the manner of their presentation differed according to conditions which have been defined as GIvt with grid and GIvt without grid . In the first case, the 2x2 square grid was present on the computer screen, while in the second case, it was not. In all the other aspects, the two procedures were the same. The complete stimuli never appeared on the screen; only the segments from which they were constituted appeared, one by one, for 1200 msec. each, with the removal of the preceding one. There were two sequences of segment presentation (easy and difficult), and these were the same as in experiments 2 and 3. The experimental design was a 2x2x12 mixed one, with the following variables: Groups, 2 levels between subjects (with and without grid); Difficulty of sequence, 2 levels between subjects (easy, difficult); Stimuli within subjects (12 levels).

Procedures. The subject was seated at a table on which a Macintosh LC personal computer screen was located about 50 cm away. Prior to the experiment, all participants were shown the answer sheet, a 2x2 grid. They were told that sequences of 8 segments would be presented on the screen. They had to connect the segments mentally in order to build the complete pattern. As soon as the last segment had disappeared, they would be expected to reproduce the complete pattern as accurately as possible on the answer grid provided. Before beginning the actual experiment, all subjects took three practice-trials, at the end of which they were asked whether they understood what was being asked of them or if they wished to take other trials. No subjects requested additional trials.

RESULTS AND DISCUSSION

The results of exp 4 are considered first by themselves and later in relation to those of experiments 2 and 3. The number of correct segments reproduced was the dependent variable.

Experiment 4. On the number of correct segments, a mixed design ANOVA was computed. The between factors were: groups at 2 levels (with and without grid), and difficulty of the sequences at 2 levels (easy, difficult). The within factor was stimuli (at 12 levels). All three main effects turned out to be significant: groups $F(1,60)=15.94$, $p=0.0002$, difficulty $F(1,60)=4.53$, $p<0.04$, stimuli $F(11, 660)=14.13$, $p<0.0001$. The interaction difficulty x stimuli was also significant $F(11,660)=2.54$, $p<0.004$.

The significance of the group effect was due to the ease of the condition with grid (x=6.03) compared with the condition without grid (x=5.3).

The significant effect of difficulty was due to a greater number of errors in the difficult condition. This means that the kind of sequence with which the segments are presented influences the result even when the segments are presented visually. It means that chunks and other types of facilitation in constructing the pattern mentally are also active when the constitutive segments are loaded visually. Let us speculate about this result. We think that it is plausible to claim that the difficulty effect, even if working in the same way in the GIvt condition in experiment 4 as in the GI condition in experiment 2, is weaker in the former case than in the latter. In fact, the post hoc analysis (Duncan, $p=0.05$) revealed that neither of the 2 conditions, namely with and without grid, was significant per se. The result is due to the synergy between the 2 groups. This evidence fits quite well with our hypothesis that the tasks used in experiment 4 are under particular boundary conditions between GI and CVT, but perhaps closer to the GI condition of experiment 2.

The effect of the variable 'stimuli' was expected, and its discussion would be the same as for experiment 2. The discussion of the interaction stimuli x difficulty also brought us back to experiment 2. In fact, the post hoc analysis of single effects showed that the result was due to 3 stimuli, namely 2, 7 and 9, which are three of the four also responsible for the same effect in experiment 2.

Given the procedural similarities, we made a comparison between the GI groups of experiment 2 (instructions given verbally) and the GIvt groups with grid of experiment 4.

On the number of correctly reproduced segments, a mixed design anova was computed. The between factors were: 'groups' at 2 levels (Gi vs GIvt), and 'difficulty' of the sequences at 2 levels (easy, difficult). The within factor was 'stimuli' (at 12 levels).

Two of the main effects turned out to be significant, namely: i) Difficulty $F(1,60)= 13.67$, $p=0.0005$; ii) Stimuli $F(11,660) = 9.88$, $p < 0.0001$. Also, two interactions were significant, namely: 'groups x stimuli' $F(11,660) = 1.94$, $p.< 0.04$; and 'difficulty x stimuli' $F(11,660)= 4.06$, $p. < 0.0001$.

The first result was expected on the basis of our hypothesis that the tasks performed by the two groups are, from a cognitive point of view, very similar, and this is the reason why a significant effect due to the differences between 'groups' did not emerge ($F(1,60)=0.39$, $p.=0.53$), whereas the effect of the 'difficulty' factor did.

The other significant effects confirmed and reinforced the results of experiments 2 and 4. Once again, the result of the interaction 'difficulty' x stimuli was due to stimuli 2, 7 and 9.

An interesting result from our point of view is the interaction 'groups x stimuli', due to the fact that stimuli 1,2,4 and 5 -which are among those judged the easiest to remember in the pilot part of experiment 1- collected more correct responses in the visual trace condition, while a better performance was registered in the GI condition by the stimuli 7,8,9 and 10, which had been judged among the most difficult to remember (see fig. 4).

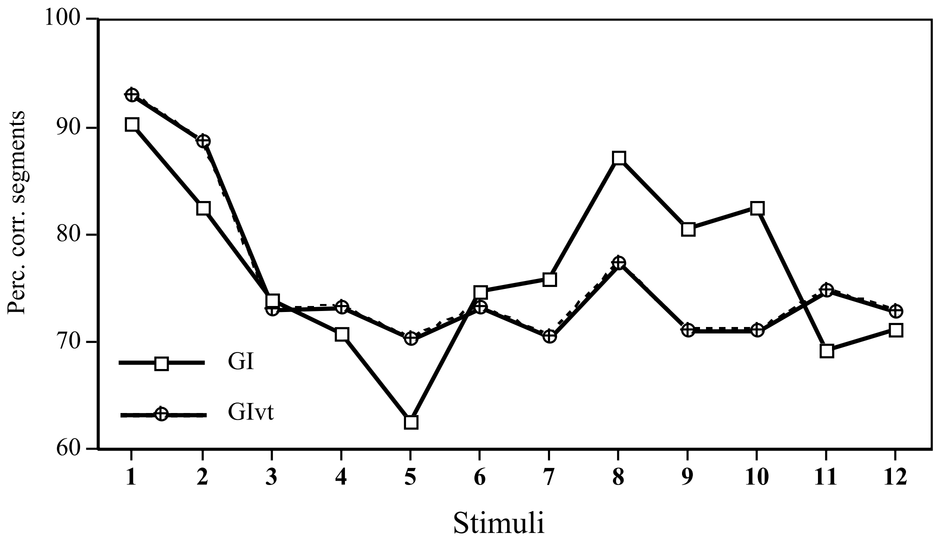

Figure 4. Mean percentages of segments correctly reproduced by subjects of the group GI of experiment 2 (directions given verbally) and the group GIvt with grid of experiment 4.

This result seems to suggest that the less complex patterns are better recalled when the information is visually given, even when the sides are presented one at the time with removal of the previous one. On the contrary, with more complex patterns a verbal instruction seems to make recall easier. These results fit well with our hypothesis advanced in the discussion on experiment 2, namely that, when the information on the segment positions is verbally given, and, therefore, the subject works only in the imagery domain, s/he seems more sensitive to chunks and partial regularities.

We also made a comparison between the CVT group of experiment 3 (permanence of the previously presented segments) and the GIvt group without grid of experiment 4. On the number of correct segments, a mixed design Anova was computed. The between factors were: 'groups' at 2 levels (i.e. the overall groups respectively tested in the two Experiments: CVT and GIvt), and 'difficulty' of the sequences at 2 levels (easy, difficult). The within factor was 'stimuli' (at 12 levels). Two of the main effects turned out to be significant, namely: 'groups' $F(1,60)=17.85$, $p.=0.0001$, and 'stimuli' $F(1,660)=13.65$, $p. < 0.0001$. Only the interaction 'groups x stimuli' was also significant $F(11,660)=3.23$, $p.= 0.0003$. Neither the difficulty effect, nor its interaction with groups, was significant, suggesting that difficult instructions do not affect memory of a figure when a visual presentation is involved as much as when only the generation of an image is involved.

The significant difference between the CVT and the Givt groups is well explained by the difference between the amount of information and the amount of cognitive activity (imagery) that were required of the participants of the GIvt in experiment 4 with respect to those of the CVT condition in experiment 3. Even when the amount of time given to the participants of experiment 4 (1200 msec x segment) was four times longer than the time given to the participants of experiment 3 (300 msec. per segment), the latter were able to perform better for every stimulus (see fig. 5). The reason is that, during the loading of information in the CVT condition, there is not a double request, probably involving more complex operations, to use both perceptual (perception of segments) and imagery processes (construction of the overall figure), while in the GIvt condition such an interference is active.

The significant interaction groups x stimuli is due, as it emerges from the analysis of simple effect, to stimuli 2, 3, 7, 9, and 12. For these stimuli, the number of correct segments was significantly higher in the CVT condition than in the GIvt one. Specific research focusing on the different visual mechanisms which process the two kinds of information (cumulative in one case and in sequence in the other one) must be performed.

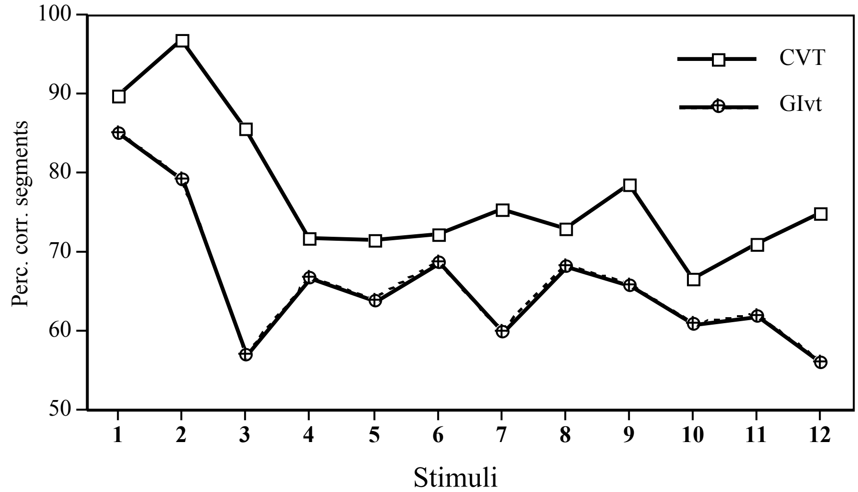

Figure 5. Mean percentages of segments correctly reproduced by subjects of the group CVT of experiment 3 (permanence of the previously presented segments) and the group GIvt without grid of experiment 4.

GENERAL CONCLUSION

In the introduction to this study, we mentioned experiments carried out in the 1970s and 1980s which aimed at reviewing the role played in imagery by those organizational-figural factors which made simple and regular ("good") forms prominent in perceptual activity. The results of those experiments were interpreted as solid proof of the hypothesis, not only of a close analogy, but also of a communality of processes between perception and imagery (Finke 1980, 1989, 1990).

The present research has demonstrated that many of the same principles of parsimony are the basis of both a VT trace derived from perceptual experience and a GI derived from imaginative processes; it is also the basis for the first recognition and easy memorization of regular and simple forms. The data confirm that the mind, even when following verbal sequential instructions, is able to generate imaginative representations having properties which are analogous to those of visual perception and different from those of linguistic representations. In fact, if the subjects recalled the linguistic instructions given to them, the elements of regularity implied in the pictorial representations, but not in the descriptions, should not facilitate their memory.

Using the present research, we also wanted to examine whether these principles functioned in the same manner within such different processes. One process (related to the VT) is activated by external, automatic, rapid, and involuntary stimuli -- we cannot decide to "not see" something before our very eyes without closing them. The other (related to the GI) is a slow, constructive, voluntary process. At the foundation of our working hypothesis is the conviction that the same principles of economy which are at the root, not only of perception, but perhaps of all cognitive activity, are applied in a different way in the case of mental imagery, so that the processing of different data (internal in the case of GIs and external in the case of the VTs), involves different procedures. In order to verify the plausibility of this hypothesis, we followed a course, which can be summarized by recalling the most significant data which emerged from the experiments.

Experiment 1 revealed that VT and GI conditions have different quantitative and qualitative effects on memory. In particular, the significant interaction of groups x stimuli was due to the fact that the pattern of correct responses for some stimuli went in opposite directions according to group (GI or VT), even though the VT group, on average, performed better. This result led us to a more careful consideration of the sequence of directions given to the GI group. In fact, many figures which caused problems for the GI group were characterized by the impossibility of anticipating elements of regularity during the creation of the image.

In experiment 2, two different instruction sequences were introduced. They were called "easy" and "difficult", depending on how much or little they allowed such expectation. In fact, the difficulty of instructions determined a marked difference on the memory of the segments of the figures. Furthermore, the interaction of groups x stimuli emphasized that some stimuli led to better performance of the GI group with easy descriptions, as opposed to that of the VT group. This held true for stimuli which were perceptually complex compared to those of the "facilitation" in the direction sequence for the GI group. Moreover, there was a substantial difference between "easy" and "difficult" directions for the GI group. Thus, the question arose as to whether the differences between "easy" and "difficult" instruction sequences reflected the properties and processing channels only of imaginative activity, or whether it was a condition of simplification and organization present in perceptual activity as well.

Experiment 3 showed that direct observation of stimulus generation in time, whether following the succession foreseen by the "easy" description or that foreseen by the "difficult" description in experiment 2, produced similar results. In fact, it was revealed that these facilitating aspects were not utilized at the perceptual level, but were in fact used at the imaginative level.

Experiment 4 gave some new and partially unexpected results. An initial unexpected piece of evidence (that cannot be called a result but rather a serendipity discovery) was found during the pilot study and involved the dramatically long time required to perform the task when the segments are presented visually, one by one, without permanence of the preceding ones. We are inclined to suppose that the system involved in the task (definable as the visual buffer or as the visuospatial working memory component) has a double function, namely, either to load input visual representations or to register the result of the imagery work. But these two functions may be activated one at a time; otherwise some kind of interference seems to slow down the process. We are aware that this is a very speculative conclusion, but future research in this direction could make the point clearer. A second interesting result was the evidence that the new GIvt condition, introduced in this experiment, is not aimed at producing a pure Generated Image, nor a pure Visual Trace, but rather something in between, as it was affected by the difficulty of instructions, but not in a particularly marked way.

The concept of chunks (Saariluoma & Sajaniemi, 1989), to which we turned in order to interpret our results, does not have unequivocal significance. The presence of many similar conditions (a sequence of verbal instruction or of visually shown segments and a sequence of figure construction) created chunks which differed in the GIs from those of the VTs. It is true that both modes utilize the economic strategy of chunks, but each one does so on the basis of its specificity. We are convinced that higher-order thinking skills (comprehension of instructions, memory, and thought), which are at the root of the GIs, utilize a different system of processing from that of perception, where the VTs originate. And even if both obey the same principles of economy, these principles are applied in different manners. The results obtained by researchers who maintain that there are common processes between imagery and perception have highlighted the presence of basic laws which both procedures obey. On the other hand, the manner in which these laws were applied in the two cases was not taken into consideration. Our results would seem to favor the hypothesis that, while imagery may produce similar results to those of perception, they are obtained through different paths.

The results of our experiments agree, in some aspects, in part with those of Palmer (1977), as some of his conclusions seem suitable also in our context. Palmer's material was partially similar to our own, as he presented 6 segment figures obtained by connecting the dots of a square lattice (3x3 dots). These 6 segment compositions had to be divided by subjects into two natural parts of three segments each; it was an easy task if the two parts were good and a difficult one if the two parts were bad. This goodness effect also emerged in a verification task in which good parts were verified more quickly and accurately than bad parts and in a mental synthesis task in which bad parts took more time and were less successfully synthesized than good parts. For our purpose, it is important to point out that in Palmer's experiments, on the basis of two different ratings of goodness, stimuli with high, medium and low goodness evaluations were used. Only high goodness rated stimuli made the tasks easier, while with both medium and low goodness stimuli, the task was difficult to the same degree. Three out of four of Palmer's experiments dealt with perception, and even though the last one dealt with imagery, it used visual traces. Since all Palmer's tasks were perceptual or perceptually grounded, his results fit only with our results related to the VT conditions. The sensitivity to medium or low goodness figures, shown by the subjects of the GI group in experiment 2 or the GIvt group with grid in experiment 4, depended on the fact that the GI stimuli were serially built in the subjects' minds. According to Palmer, good parts may be processed in a qualitatively different way from bad parts. Perhaps the simplest general type of process capable of accounting for these results is one in which good parts can be matched holistically and in parallel, while bad parts must be matched componentially and serially (1977, p. 470). Our results showed that, during the componential construction of Generated Images, some partial and/or temporary nucleus of goodness could affect serial but not holistic processes. In fact, from experiments 3 and 4 (GIvt group without grid), it emerged that if we try to make a holistic process, such as perception, serial, it does not benefit from the same advantages as a serial process in such a way as to generate images from verbal instructions.

The experiments presented in these pages add evidence to the line of research where aspects of imaginative activity are compared to those of perceptual activity in parallel tasks, but it is shown that perception and mental imagery do not always present identical effects (e.g. Intons-Peterson & McDaniel, 1990). We have extended this method of parallel tasks to a case (visual trace) which, on the one hand, can be considered related to imagery activity (as it involves visual representations maintained even when the perceived objects are no longer available), and, on the other hand, can be considered related to visual perception (as the representation originates directly from a visual experience). A contrast between visual traces and generated images allowed us to collect data from which we can make acceptable deductions about the nature of similarities and/or differences between the processes which are the foundation of perception and imagery, respectively. We believe, in fact, that to make inferences about the similarities between perception and imagery, without a clear operating differentiation within the imagery field, is an overstep which risks missing important discriminative steps. According to our point of view, the lower-order perceptual skills, which are automatic and encapsulated and which give form to mental images precisely because they are impervious to influences and corrections from higher-order thinking skills, cannot be triggered by voluntary cognitive activity.

RESUMEN

Se ha constatado que la regularidad de una figura ayuda tanto a su percepción como a su recuerdo. Este artículo examina la manera en que la regularidad de un patrón puede influir en el recuerdo de la figura en comparación con el de imágenes generadas. También se examina como configuraciones específicas pueden afectar el recuerdo. Se asume que un trazo visual y una imagen implican mecanismos psicológicos parcialmente diferentes y que el recuerdo de una imagen se ve afectado por la manera en que se construyó. En los cuatro experimentos que se presentan, se pidió a diferentes grupos de sujetos que dibujarán figuras simples basándose en su presentación pictórica (TV= Trazo Visual) o en la imagen generada mediante el seguimiento de instrucciones (IG= imagen generada). El experimento 1 muestra que la condición TV produce generalmente peor recuerdo que la condición IG , aunque esta diferencia solo ocurre con alguna figuras. El experimento 2 muestra que las dificultades y peculiaridades de la condición IG dependen de hasta qué punto el sujeto puede encontrar regularidades parciales durante la construcción de la figura. Este resultado no se observó en la condición VTC (Trazo visual construido) en la que de forma progresiva se mostraban segmentos de la figura. (Exp. 3). El efecto aparecía pero en menor magnitud que en la condición IG cuando se presentaban simples segmentos y se pedía al sujeto que imaginase el patrón global resultante (Exp. 4).

Palabras clave: Percepción, representación, memoria visual.

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