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Scanning Visual Images Generated from Verbal Descriptions

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Mental scanning studies have consistently shown that the longer the distance between two points of an imaged configuration, the longer the scanning time for this distance. In typical mental scanning experiments, the images explored during the scanning task reproduce configurations which have been perceptually processed by subjects in a previous learning phase. In the present study, this condition was replicated and extended to a new condition where subjects scanned over images they had elaborated from the verbal description of a spatial configuration. This condition produced a pattern of results highly similar to those obtained in classic experiments, i.e. a linear relationship between distances and scanning times. With additional learning of the verbal description, the correlation coefficient increased, and scanning times decreased, both reaching values comparable to those obtained in the condition involving perceptually based images. These findings support the assumption that the mechanisms governing mental scanning apply to either sort of image—those derived from perceptual processing and those constructed from the processing of discourse.

In recent years, considerable research has been devoted to the investigation of the functional similarities between mental imagery and perception (see, e.g. Denis, 1989; Finke, 1985; Kosslyn, 1980; Paivio, 1986; Shepard & Cooper, 1982). There is a general consensus that images are psychological events which are qualitatively distinct from perception.

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However, there is growing empirical evidence that imagery provides individuals with cognitive representations that can be utilised in a way comparable to outputs of perception, with behavioural consequences often similar to those of perception (cf. Farah, 1985; Finke & Kurtzman, 1981; Freyd & Finke, 1984; Podgorny & Shepard, 1978). These similarities are the basis for the widespread assumption that imagery not only derives from perceptual experience, but is intimately related to perception, in that both rely on common mechanisms which operate upon shared (or partly shared) neural pathways (Farah, 1988; Farah, Péronnet, Gonon, & Giard, 1988; Kosslyn, 1987; Pinker, 1988).

Although it is widely recognised that most of our mental imagery derives from perceptual experience, few studies have explored the mechanisms by which people use verbal descriptions to create images of objects unknown to them. There are numerous natural communicative situations where one individual produces a linguistic description, and another elaborates an image of the described object he or she may have never seen or heard about before. Most people are able to process linguistic descriptions in order to construct such visual mental representations (e.g. Denis, 1982; Foos, 1980; Perrig & Kintsch, 1985). The issue is whether mental images devoid of a perceptual basis possess characteristics which make them comparable to images derived from perceptual processing. For instance, an individual may need to perform computations on the mental image of a map (e.g. find the shortest distance between two points). Will these computations be as valid on images deriving from verbal descriptions as on images deriving from perceptual experience?

This was the original motivation for a research programme designed to investigate the processes that individuals implement to exploit cognitively the information contained in images derived from either perception or from descriptions. In the initial step of this programme, which is reported here, the first type of process investigated was mental scanning. One of Kosslyn's major findings is that when a person scans over the visual image of a previously learned configuration, scanning durations are linearly related to the distances scanned (Kosslyn, 1973; Kosslyn, Ball, & Reiser, 1978). This finding is generally taken by imagery researchers to reflect the structural isomorphism of mental images with the objects or configurations they represent. Kosslyn's experiments also provide evidence that information on a given feature may be stored in non-imaginal formats. However, when this information is embodied in a visual image, it is organised in a way which reflects the spatial structure of the configuration, in particular as concerns relative distances between features.

Other researchers have argued that mental scanning effects only reflect subjects' knowledge of the imagined objects and of what would be the actual (perceptual) scanning times for these obejcts (cf. Goldston, Hinrichs, & Richman, 1985; Mitchell & Richman, 1980; Pylyshyn, 1981; Richman, Mitchell, & Reznick, 1979). Another objection is that the effects of distance on scanning times reflect subjects' compliance with experimenters' expectations (Intons-Peterson, 1983). Further research in fact provided evidence that mental scanning effects cannot be reduced to tacit knowledge effects (Finke & Pinker, 1982; 1983; Pinker, Choate, & Finke, 1984; Reed, Hock, & Lockhead, 1983; see also Denis & Carfantan, 1985), and that experimenter effects and task demands cannot be taken as sufficient explanations for mental scanning effects (cf. Jolicoeur & Kosslyn, 1985).

The experiments described below are designed to compare time–distance relationships when the visual image constructed by a subject arises from either the processing of a verbal description or the processing of a visual stimulus.

EXPERIMENT 1

In order to investigate mental scanning effects subsequent to the processing of either visual or verbal material, we devised a configuration which could be described unambiguously by a short text. This configuration was the map of a circular island having six features situated at the periphery, at locations which could be precisely defined by a conventional coding system. This map was first used to replicate the typical scanning effect following perceptual learning. In this condition, Kosslyn's original procedure requiring subjects to mentally scan over intervals separating specified points of the configuration, was used (cf. Kosslyn et al., 1978, experiment 2). For the part of the experiment extending to a condition with description-based images, we devised a short text describing the island. During the test phase, the procedure involved the same mental scanning process over intervals as above.

In addition, a perceptual scanning (control) condition was included in the experiment. The classic interpretation of mental scanning experiments is that the linear relationship between scanning times and distances reflects the structural similarity of the image to the perceived configuration. The tacit assumption is that this linear relationship holds true in a condition where subjects perform perceptual scanning on the configuration itself. Surprisingly, however, controls for this condition have apparently not been reported in the mental scanning literature.[1] For this reason, we included a condition of this type to ensure that perceptual scanning exhibits the

[1]Intons-Peterson (1983, experiment 2) and Jolicoeur and Kosslyn (1985, experiment 3) used a perceptual scanning condition. The primary motivation for this condition, however, was the assessment of experimenter effects on scanning times.

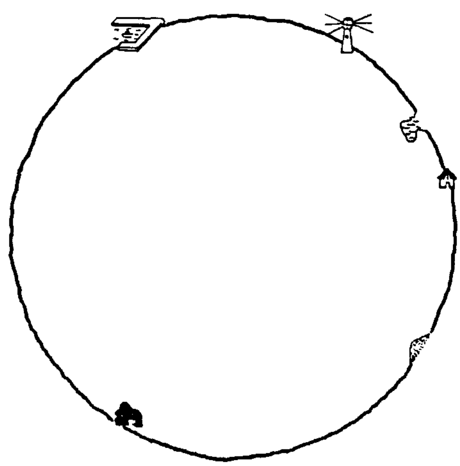
TABLE 1
Summary of the Three Conditions in Experiment 1

Condition	*Material During Learning Phase*	*Task on Test Phase*
1. Scanning of perceptually presented configuration	(No learning phase)	Perceptual scanning
2. Scanning of perceptually based images	Map	Mental scanning
3. Scanning of linguistically based images	Text	Mental scanning

regularities which are assumed to be transferred to imaginal conditions. Table 1 summarises the three conditions investigated in this experiment.

Method

Subjects. Thirty undergraduates from the Orsay campus were recruited as subjects. Each subject was randomly assigned to one of the three conditions.



Text (original in French)
The island is circular in shape. Six features are situated at its periphery. At 11 o'clock, there is a harbour. At 1, there is a lighthouse. At 2, there is a creek. Equidistant from 2 and 3, there is a hut. At 4, there is a beach. At 7, there is a cave.

FIG. 1 Map and text used in the experiment.

Materials. A map of a fictional island was constructed (see Fig. 1). The map was circular in shape, with six features situated at the periphery (harbour, lighthouse, creek, hut, beach, cave), at locations which could be unambiguously defined in the conventional hour-dial terms of aerial navigation. The six features were located in such a way that all the distances between pairs of adjacent features were different from each other. The precise location of each feature on the map was indicated by a red dot.

A text was written, describing the island and the location of the six features (see Fig. 1). Features were introduced in the description in clockwise order, starting with the harbour. The French words for these features are all pronounced as one-syllable words.

A tape-recording was constructed containing 60 pairs of words. Each feature was named ten times and was followed 4 sec later by a second word. On five of these trials, the second word did not name a feature on the map. The "false" objects were features that could reasonably have been included on the map (meadow, bridge, well, mine, moor). On the other five trials, the first word was followed by the name of each of the other five features. Thus, every pair of features occurred twice, alternating the feature which appeared first. Order of pairs was randomised, with the constraints that the same feature could not occur twice in two successive pairs, that a "true" feature occurring as the second member of a pair could not occur in the next two pairs, and that no more than three "true" or three "false" trials could occur in a row. Presentation of the second word started a clock. A new trial began 8 sec after the probe word was presented. The test trials were preceded by eight practice trials (four "true" and four "false"). The practice trials used names of French cities as "true" items. The whole procedure was driven by a computer program adapted to the needs of this experiment.

Procedure. In condition 1, subjects were seated facing the map. The map, which measured 58 cm in diameter, was taped to a board placed 140 cm from the subjects. The experimenter first gave the subjects the names of the six features. The subjects were then asked to study the map for 1 min. Next, they were told that for each trial, they would hear the name of a feature on the map. They were then to focus visually on the feature named. Subjects were told that a few seconds after focusing on the named feature, another word would be presented. If this word named a feature present on the map, the subjects were to scan to it visually along the shortest straight line and depress a button with their dominant hand when they arrived at the dot centred on the feature. If the second word of a pair did not name a feature on the map, the subjects were to depress another button placed before them with their non-dominant hand. The clock was stopped when either button was depressed, and response times were recorded. The experimenter interviewed the subjects during the course of the practice trials, making sure that they were following the instructions.

In condition 2, the procedure closely followed that used by Kosslyn et al. (1978, experiment 2). During the learning phase, the subjects were shown the map in the very same way as in condition 1. First, they studied the map, closed their eyes and imagined it, and then compared their image to the map until they thought their image was accurate. Then, they were provided with an outline of the map drawn on a sheet of tracing paper, and were asked to mark the exact locations of the six features (marking the locations of the red dots centred on the features). Following this, the subjects were invited to compare their drawing with the original map by superimposing the former on the latter. This procedure was repeated until all six marks were within 1 cm of the respective actual locations. Between two and four drawings were required for subjects to achieve this.

At the beginning of the test phase, subjects were told that each trial would first consist of hearing the name of a feature on the map. They were to picture the entire map mentally and then focus on the feature named. Subjects were told that a few seconds after focusing on the named feature, they would hear another word. If this word named a feature depicted on the map, the subjects were to scan to it and depress a button with their dominant hand when they reached the dot centred on it. The scanning was to be accomplished by imagining a little black speck zipping along the shortest straight line from the first feature to the second. The speck was to move as quickly as possible, while still remaining visible. If the second word of a pair did not name a feature on the map, the subjects were to depress the second button with their non-dominant hand. Response times were recorded. The experimenter interviewed the subjects during the practice trials, making sure that they followed the instructions about imagery use.

In condition 3, in the learning phase, the subjects were told that they would hear a description of the map of an island. They were told that they would have to create as vivid and accurate a visual image of the map as possible. The text was presented auditorily three times.[2] Following each text presentation, the subjects were required to form a visual image of the map and revise the exact location of each feature. The test phase then proceeded exactly as the test phase for condition 2.

All subjects were tested individually. At the end of the experiment, the subjects assigned to conditions 2 and 3 were interviewed. Those who

[2]This number of learning trials was defined after a pilot experiment involving 10 subjects from the same population. This experiment showed that no more than three trials were necessary for all the subjects to recall the locations of the features on a blank map accurately.

reported having followed the imagery instructions less than 75% of the time during the test phase were excluded and replaced. In addition, the subjects in condition 3 were asked whether before mentally scanning to the second named feature they had either relied on the location of the feature depicted in their visual image or first revised the hour-coded location of the feature. The subjects who stated having used this latter procedure were excluded and replaced.

In all three conditions, during the test phase, five subjects processed the items according to the randomised order defined above, whereas the other five subjects first processed the second half of the items, then the first half.

Results and Discussion

For each condition, only the times for the correct "true" decisions were analysed. Times exceeding twice the other time for the same distance were discarded. Subjects did not produce any errors in conditions 1 and 2, and the overall error rate was very low in condition 3 (0.3% of the trials).

Condition 1. Subjects' times for the different distances were analysed first. The analysis of variance (ANOVA) revealed a marked effect of distance on scanning times [$F(14,126) = 4.00$, $P < 0.001$], with times increasing linearly with increasing distance [$F(1,9) = 13.45$, $P < 0.01$]. In addition, times were averaged over subjects and the correlation between times and distances was calculated. The coefficient obtained was $r(13) = 0.89$, $P < 0.01$ (see Fig. 2).

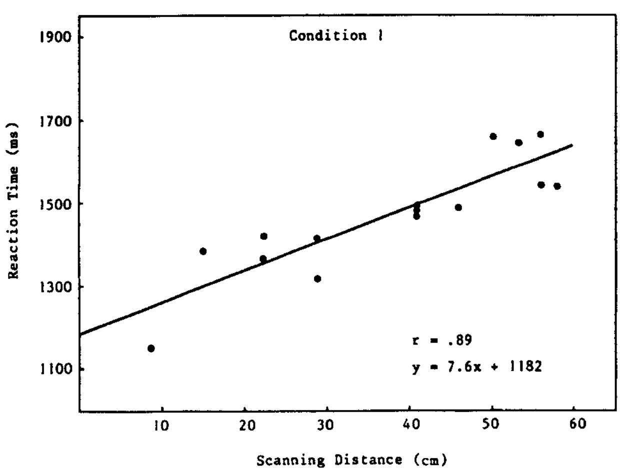


FIG. 2 Experiment 1: Reaction time as a function of scanning distance (condition 1).

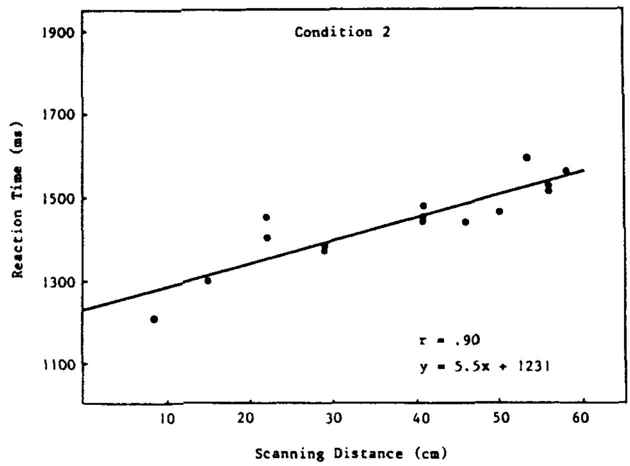


FIG. 3 Experiment 1: Reaction time as a function of scanning distance (condition 2).

Condition 2. The ANOVA showed a consistent increase in scanning times as a function of distance [$F(14,126) = 3.57$, $P < 0.001$], with a significant linear component [$F(1,9) = 18.52$, $P < 0.005$]. The correlation between times (averaged over subjects) and distances was $r(13) = 0.90$, $P < 0.01$ (see Fig. 3).

In this standard mental scanning condition, the results show a clear confirmation of the linear relationship between scanning times and distances, as previously evidenced by Kosslyn et al. (1978). In addition, comparison with the data from condition 1 indicates a quite similar pattern of time–distance correlation. An analysis combining the data from conditions 1 and 2 reveals no substantial difference between the average absolute durations of perceptual and mental scanning. The findings from the perceptual condition thus provide objective support for the notion that the rules which govern the processing of mental images closely resemble those which underly perceptual processing. The postulate of isomorphism is thus strengthened by these data.

Conditon 3. The ANOVA revealed a significant effect of distance on response times [$F(14,126) = 2.20$, $P < 0.01$], with a strong linear component [$F(1,9) = 14.57$, $P < 0.005$]. The time–distance correlation was $r(13) = 0.65$, $P < 0.01$ (see Fig. 4).

The existence of a significant correlation between scanning times and distances in condition 3 provides grounds for the claim that the rules which govern mental scanning are valid for representations deriving from perception as well as for representations deriving from text processing. However, the correlation was somewhat lower for the linguistically based than for the

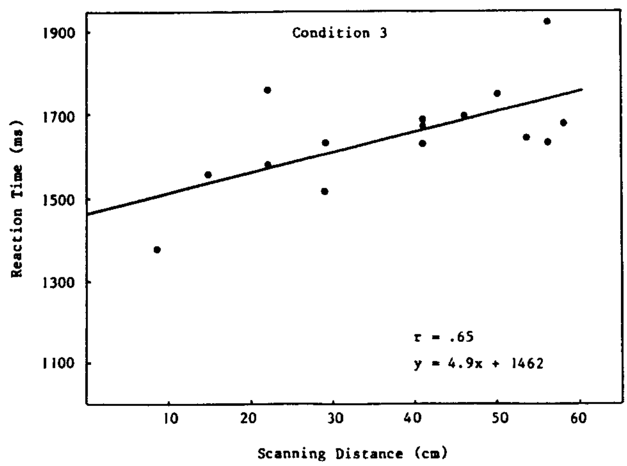


FIG. 4 Experiment 1: Reaction time as a function of scanning distance (condition 3).

perceptually based image. Although this difference was only marginally significant [$\chi^2(1) = 2.86$, $P < 0.10$], it may indicate that in the conditions tested here, the image resulting from text processing did not attain the structural coherence or stability of a perceptually based image, and thus could have introduced some noise during the scanning process. The dispersion of points in Fig. 4 (as compared to Fig. 3) also supports the hypothesis of lower image resolution following text processing. In addition, the comparison of data from conditions 2 and 3 reveals that the absolute scanning times were substantially longer for linguistically based images (by 209 msec on the average), which suggests that specific constraints have affected mental scanning in this condition.

These differences may reflect the fact that the construction of the representation was not completely finished when the scanning process took place. There is no doubt that the verbal information transmitted by the text was fully memorised after three learning trials, but the visual representation itself could at this time have been insufficiently consolidated. In order to assess this hypothesis, we involved subjects in additional learning before testing them for scanning.

EXPERIMENT 2

This experiment consisted in replicating condition 3 of Experiment 1, but subjects were submitted to six (rather than three) presentations of the text describing the island. On each presentation, subjects were instructed to visualise the map and place each feature at its exact location. We expected that these objects would be in a position to create a more *coherent*, *better* integrated image, thus producing a clearer time–distance relationship in mental scanning.

Method

Subjects. Ten undergraduates who had not participated in the previous experiment were recruited as subjects in Experiment 2.

Materials. The materials used were identical to those used in condition 3 of the previous experiment.

Procedure. The procedure used in this new condition (condition 4) replicated the procedure of condition 3, except that the subjects heard the description of the map six times.

Results and Discussion

The overall error rate was very low (1.7% of the trials) and errors did not vary systematically with distance scanned.

The ANOVA revealed a significant effect of distance on scanning times [$F(14,126) = 4.57$, $P < 0.001$], and times increased linearly with increasing distance [$F(1,9) = 24.57$, $P < 0.001$]. When scanning times were averaged over subjects, the correlation between times and distances reached $r(13) = 0.91$, $P < 0.01$ (see Fig. 5).

The new learning condition thus yielded a substantially higher correlation than previously. The coefficient now reached a value comparable to the one obtained in the standard mental scanning condition (condition 2).

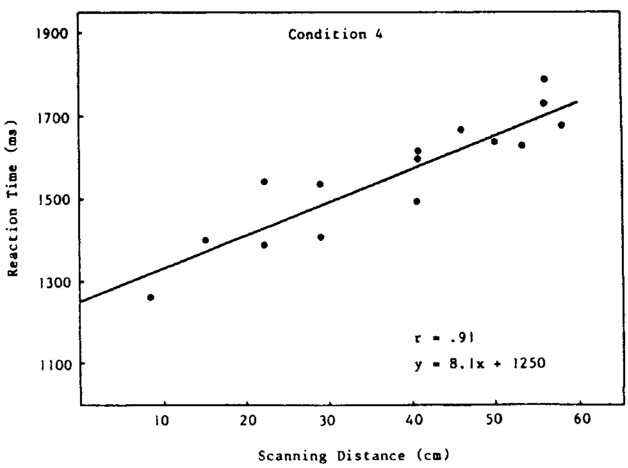


FIG. 5 Experiment 2: Reaction time as a function of scanning distance (condition 4).

This finding indicates that the difference between the correlation coefficients in conditions 2 and 3 can partially be accounted for by insufficient processing of the text in condition 3. In addition, scanning times tended to be shorter in condition 4 than in condition 3, and their absolute values did not differ from those obtained in condition 2 after perceptual processing. Differences between conditions 3 and 4 with respect to the dispersion of points (see Figs 4 and 5) also reflect the effects of additional learning on the consistency of the image to which the scanning process was applied.

Overall, these findings suggest that for a moderate rate of learning, an image constructed from text does not attain the coherence of an image derived from perception, with the consequence that a certain amount of error contaminates the scanning process. With additional learning, the image derived from text reaches a structural coherence and resolution which make it cognitively exploitable in conditions practically identical to those characteristic of perceptually based images.

EXPERIMENT 3

The amount of text processing is only one of the factors likely to affect the consistency of a visual image generated from this text. A further experiment was devised to explore another factor expected to increase the similarity of linguistically and perceptually based images. In the conditions involving text processing (conditions 3 and 4), we collected post-experimental reports indicating the variety of sizes of the island imagined by the subjects. It was our original intention not to place any constraints on size for image construction. However, individual variability in image size might increase variability of scanning times. We thus replicated the original condition based on text processing with three learning trials, with subjects being given explicit information on the size of the image to be constructed. It was expected that reducing inter-individual variability through this procedure would yield better evidence on the time–distance correlation in mental scanning.

Method

Subjects. Ten undergraduates who had not participated in the previous experiments were recruited as subjects in Experiment 3.

Materials. We used the same materials as in condition 3 of Experiment 1.

Procedure. The procedure used in this new condition (condition 5) replicated the procedure for condition 3, except that the experimenter provided subjects with explicit information on the size of the image to be constructed. The nominal size was that of the actual map used in conditions 1 and 2. While listening to the instructions, the subjects were shown a blank sheet on which the map was to be imaged. The dimensions of this sheet were such that the image of the island could be inscribed on it, and be identical in size to the actual map in conditions 1 and 2.

Results and Discussion

The overall error rate was very low (2.7% of the trials) and errors did not vary systematically with distance scanned.

The ANOVA revealed a significant effect of distance on scanning times [$F(14,126) = 5.06$, $P < 0.001$], with a strong linear component [$F(1,9) = 24.64$, $P < 0.001$]. The correlation between scanning times and distances was $r(13) = 0.87$, $P < 0.01$ (see Fig. 6).

This correlation was much higher than in the comparable condition (condition 3). Comparison of Figs 4 and 6 indicates that the dispersion of points was substantially attenuated in condition 5. In addition, the absolute scanning times were virtually the same as in the case of perceptually based images. Variance among subjects for scanning times was also attenuated. While the standard deviation of scanning times averaged over the 15 distances was 396 for condition 3 and 406 for condition 4, it dropped to 342 in condition 5.

These findings suggest that with a minimal amount of learning, the structural coherence of linguistically based images can be enhanced when

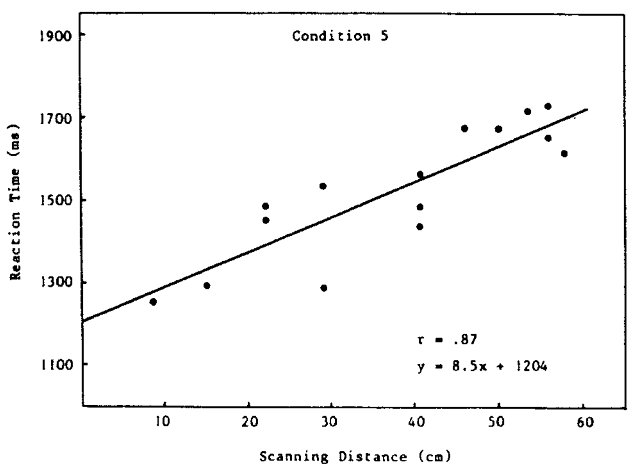


FIG. 6 Experiment 3: Reaction time as a function of scanning distance (condition 5).

explicit instructions are given to subjects on the size for image construction. In addition, this procedure substantially reduces scanning time variability among subjects.

GENERAL DISCUSSION

The research reported in this paper first replicated the typical outcome of mental scanning studies: The longer the distance between two points of an imaged configuration, the longer the scanning time for this distance. In addition, time–distance regularities in mental scanning correspond closely to those observed in perceptual scanning. The most novel aspect concerned the situation where subjects were asked to generate and scan over images of configurations to which they had no prior perceptual access, but which they had elaborated from a verbal description. Mental scanning effects were clearly evidenced in this condition, and it was also shown that greater processing of the description in the learning phase led to clearer mental scanning effects. This latter finding suggests that if visual images generated from discourse have properties similar to those of perceptually based images (here, the properties revealed by mental scanning), they do not exhibit all these properties at once. The referential validity of images—that is, their capacity to reflect adequately the objects they refer to—is therefore not an all-or-nothing property, but rather results from stepwise elaboration. Finally, among the factors likely to increase the similarity of linguistically based to perceptually based images, the findings show that specifying the size at which an image should be constructed enhances the demonstration of time–distance relationships in images generated from discourse.

A very important point is that text or discourse effectively allows people to construct representations which entertain structural isomorphism with described objects, as do images resulting from perceptual processing of these objects. Equally important, the representation constructed from text not only contains those pieces of information which were explicitly stated (for instance, that there is a harbour at a given location), but also contains metric information which was not made explicit at any time in the text (information regarding the relative distances between features). The capacity of description-based images to display non-explicit information derives from an important representational property inherent in visual imagery; that is, specifying locations of subparts of the representation necessarily makes the relative positions of these subparts evident (cf. Kosslyn, 1980; Rumelhart & Norman, 1988).

Finally, the findings converge on the notion that the processing of verbal information generates mental representations which should be considered to be genuinely visual. Making a claim for the visual character of images does not imply that these cognitive entities necessarily represent information acquired through visual perception. Rather, images constructed from discourse can be qualified as visual in the sense that they use the same cognitive apparatus as visual imagery derived from perceptual processing (cf. Farah, 1988). It is clear from our experiments, that provided sufficient time or practice is devoted to learning, text information can be used to construct a representation whose structural properties are highly similar to those of perceptually based images.

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