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Only stimulus energy affects the detectability of visual forms and objects

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A detection task was performed using different pictographic representations of objects in order to test the hypothesis that high-level information (familiarity) may influence detection thresholds. The stimuli were five versions of forms: outline drawings of objects, silhouettes, and three fragmented versions of forms derived from the outlines. The stimuli varied on two parameters: their nameability (easily nameable, hardly nameable, and not nameable) as assessed by a naming task, and their energy content as assessed by a two-dimensional fast-Fourier transform. The greatest amount of energy was observed for silhouettes, and the amount of energy contained in the vertical and horizontal spatial frequency components was equivalent for outlines and the three versions of fragmented forms. Luminance thresholds for the detection of the forms were measured by means of an adaptive method. The results show that thresholds were determined only by the energy content of the stimuli. High-level semantic or name information had no influence on the detectability of the visual signal. The results are discussed in terms of the visibility of spatial frequency components at detection threshold.

Most of the experiments reporting an object-superiority effect or, more generally, a context effect, involve identification of a part of a configuration: for example, a line segment in a cube-like form (Enns & Gilani, 1988; McClelland & Miller, 1979; Weisstein & Harris, 1974), a letter in a word (Baron, 1978), or a facial feature in an outline drawing of a face (Homa, Haver, & Schwartz, 1976; van Santen & Jonides, 1978). These experiments raise at least two questions. The first one concerns the generality of such findings to other tasks; that is, do context effects occur at low levels of processing such as detection thresholds? The second question concerns the mechanisms responsible for such effects: Do they result from a top-down influence on perceptual processing or from decisional processes occurring beyond these early stages?

Two recent studies have revealed evidence of a context-superiority effect in a detection task (Gorea & Julesz, 1990; Purcell & Stewart, 1988). In Purcell and Stewart's experiments, a two-alternative spatial forced-choice method with a masking procedure was employed. The stimulus onset asynchrony was used as a dependent variable to estimate the detection threshold. In Gorea and Julesz's experiment, vertical and horizontal line segments were embedded in an array of oblique elements. The thresholds to detect the target were measured by a two-alternative temporal forced-choice method. The dependent variable was the difference in angle between the distractors (oblique lines) and the target. In both studies, the detection threshold was lower for an upright face-like stimulus as the target than for an inverted face (Purcell & Stewart, 1988), or for a meaningless pattern of vertical and horizontal line segments (Gorea & Julesz, 1990). However, although the face-detection task was formally described as a detection task, it can be argued that a discrimination was necessary for its achievement.

These experiments raise the question of the distinction between detection and identification or perfect discrimination (Watson & Robson, 1981). In each of the aforementioned experiments, the target could be identified at its detection threshold. However, there are conditions in which no (complete) identification can be achieved at identification thresholds. Numerous experiments performed on simple stimuli (gratings varying in spatial frequencies or orientations) have shown that the detection threshold can be equal to the identification threshold when the spatial frequencies or the orientations are processed by independent sensory channels (see Olzak & Thomas, 1986, for a review). These experiments generally use a two-alternative spatial or temporal forced-choice method, in which the subject's task is to detect the presence of a stimulus and to identify its spatial frequency or its orientation among two or more alternatives (Gorea, Demany & Bonnet, 1986; Thomas, 1985; Watson & Robson, 1981). The results indicate that detection never occurs without some degree of identification of some physical characteristics of the stimulus.

When thresholds are measured in terms of the energy (i.e., luminance) just necessary to detect the visual signal, this energy may be sufficient to detect the presence of a light of a given size or a given orientation but may not be sufficient to identify all of its spatial characteristics completely. In these conditions, one can expect that complete identification is impossible and no context-

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superiority effect can occur, because the necessary information is not available for the visual system. The present experiment was thus designed to test the hypothesis that detection thresholds are determined only by their energy content and that high-level information has no influence at the sensory level of processing.

METHOD

Subjects

The subjects were 3 postgraduate students in the laboratory of experimental psychology (University Paris V) and 1 of the authors (M.B.). The students were naive as to the purpose of the experiment. All subjects had normal or corrected-to-normal vision.

Stimuli

Twenty-five forms were used as stimuli. The stimulus set was composed of five outline drawings of objects (crocodile, rabbit, sailboat, hen, and fish), the five silhouettes of these objects, and three fragmented versions, of each form derived from the outline drawings and varying in nameability. The three fragmented versions were elaborated either by a permutation of the fragments within the virtual contour (e.g., Figures 1C and 1D), in which case the location of the local densities of fragments was maintained, or by changing the orientation of the fragments (e.g., Figures 1C and 1E) while keeping them at the same location. The nameability of the fragmented versions was assessed by a naming task completed by 60 subjects. This preliminary experiment was performed on an initial set of 26 fragmented forms per version. Since the three fragmented versions of each figure were derived from the same outline drawing, the stimuli were presented to independent groups in order to avoid carryover effects. The forms were sequentially displayed for 150 msec in the center of the screen. The 26 stimuli of each version were repeated three times in succession. The subjects' task was to name the figure. Both exact names and category names were accepted as correct identification, but only names given by at least 80% of the subjects and repeated across the three presentations were taken into consideration. The fragmented forms used in the present experiment were selected on the basis of the results of the naming task. The selection criterion was that the nameability of the form varied in the three fragmented versions. The percentage of correct naming averaged across the five forms and the three repetitions was 72, 45, and 14, respectively, for the easily nameable, hardly nameable, and not nameable versions. The outline drawings and the silhouettes could be named without ambiguity.

A two-dimensional fast-Fourier transform was performed on the five versions of each form. As expected, the spectrum of the silhouettes contained the greatest amount of energy. The three fragmented versions all contained the same amount of energy. The lowest amount of energy was found in the outline drawings, but the energy displayed in the vertical and horizontal fundamental components was similar for these stimuli and their fragmented versions.

Procedure

The stimuli were displayed on a high-resolution black-and-white video monitor (Visionor Model M51 CHR 1007; Lille, France). They were generated through an IBM-compatible computer (Olivetti M24) equipped with a special graphic adapter (Galaxy SA 1019A; Evroz, Tel-Aviv), providing a display of 1,024 × 768 pixels at a rate of 60 Hz (noninterlaced). The size of a pixel was 0.36 × 0.36 mm. Gray levels were obtained by combinations of red, green, and blue signals carefully calibrated with a Minolta CS 100 photometer.

The luminance of the background was set at 2.08 cd/m². At a viewing distance of 57 cm, the angular size of the forms was 2° horizontally and vertically for three figures (rabbit, hen, sailboat) and 2° vertically and 3.5° horizontally for the other two figures. The exposure time was set at 33 msec. The stimuli were centrally displayed.

Thresholds were measured by means of an adaptive yes/no procedure adapted from Tyler (1987). A staircase procedure was developed in order to obtain a rapid convergence of the gray values around the asymptotic threshold level. On each trial, the stimulus could be present or absent with an equal probability. The subject indicated a *present* or *absent* response on two response keys. The gray values of the *present* stimuli were determined by the response: increment followed an *absent* response, decrement followed a *present* response. With the exception of the first five trials, the amplitude of the steps was constant (about 0.05 cd/m²).

In order to start the threshold measurement as near as possible to the expected threshold, the initial gray value was determined after five trials by means of a halving procedure. The staircase procedure was then run as described above until threshold was reached. The procedure was then terminated and the threshold was obtained when the two following conditions were met: the slope of the function relating the values of the stimulus to the rank of the trial was equal to zero ±0.1, and the percentage of correct detections was 75%±10%. An average of 45 trials was necessary to reach the threshold for each figure.

The 25 forms were presented in five blocks of five forms. Each block was composed of a silhouette, an outline, and three fragmented forms varying in their nameability. The five versions of each figure were presented in five different blocks. Each block was repeated three times, yielding 15 experimental sessions of about 30 min each. A practice session on five forms was given at the beginning of the experiment.

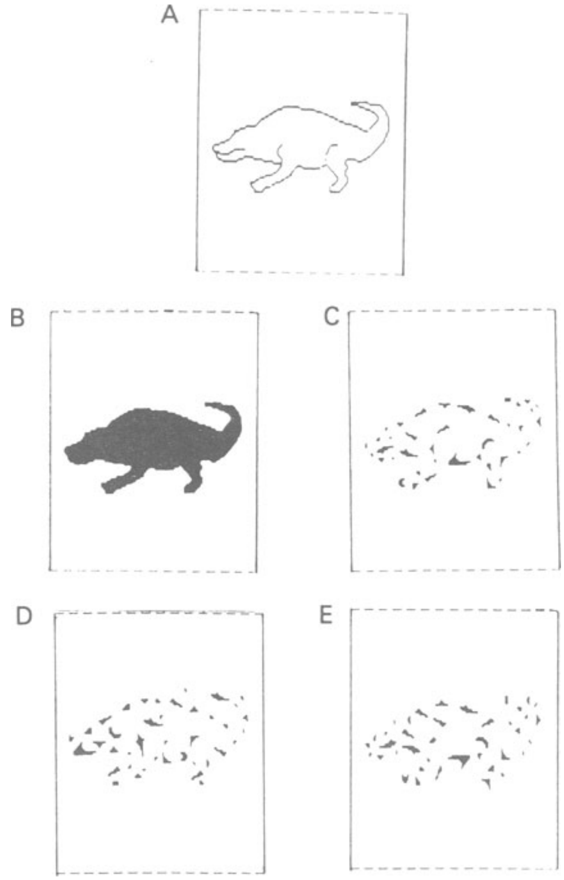

Figure 1. An example of the five versions of forms of one of the figures used in the experiment: (A) outline drawing, (B) silhouette, (C) easily nameable fragmented form, (D) hardly nameable fragmented form, and (E) not nameable fragmented form.

RESULTS

Two analyses of variance, one on the subjects and one on the figures as random factors, were carried out. The

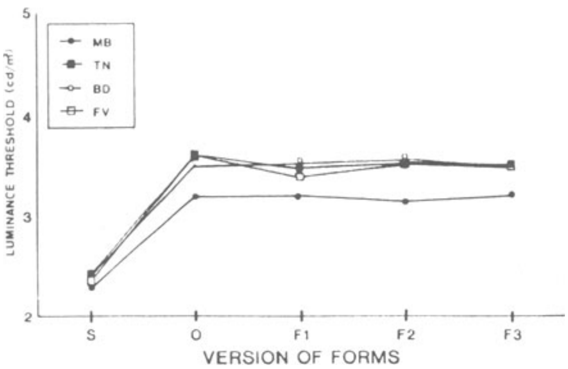

Figure 2. Mean detection thresholds (in cd/m²) for the 4 subjects (M.B., T.N., B.D., and F.V.) averaged across the five versions of each figure and the repetitions. S = silhouette, O = outline drawing, F1 = easily nameable fragmented form, F2 = hardly nameable fragmented form, and F3 = not nameable fragmented form.

variables were the version of the forms, the blocks, and the repetition.

The mean luminance thresholds for the three repetitions were 3.22, 3.25, and 3.21 cd/m² ($F < 1$). There was no effect of block. The only significant main effect was that of version of the forms [subjects, [$F(4,12) = 179.5$, $p < .001$; figures, $F(4,16) = 200$, $p < .001$], with the lowest detection threshold for silhouettes (2.36 cd/m²) and equivalent thresholds for the outline drawings (3.49 cd/m²) and the three fragmented versions (3.41, 3.44, and 3.44 cd/m², respectively, for the easily nameable, hardly nameable, and not nameable versions). There was no effect ($F < 1$) of version of the forms when the silhouettes were excluded from the analysis. As can be seen in Figure 2, all 4 subjects displayed the same pattern of results.

DISCUSSION

The results of this experiment show that absolute detection thresholds are determined only by the energy content of the stimuli. If high-level processes such as semantic or name information influence early sensory processes (Purcell & Stewart, 1986, 1988), the lowest detection threshold should have been observed for outline drawings, followed by silhouettes, since outlines have been demonstrated to be easier to identify than silhouettes (Riddoch & Humphreys, 1987), and then by the fragmented forms. This was clearly not the case. Studies reporting an effect of high-level semantic information on the detectability of a visual signal (Doyle & Leach, 1988; Purcell & Stewart, 1986, 1988) have typically used presentation conditions (e.g., exposure time, level of contrast, type of mask) that allow high-level information to be available (Boucart & Humphreys, 1990, Note 1). In the present experiment, only some physical information, such as the energy contained in some spatial frequency components, was available. As stated by Campbell and Robson (1968), the detection threshold is reached as soon as some of the components reach their own threshold. At a sensory level of processing, the visual system acts as a filter. This filter can be characterized by the contrast-sensitivity function. As a consequence of this filtering, some of the components, although present in the physical stimulus, are not visible to the organism (Bonnet, 1989). The outline drawings and the fragmented versions differed only in their high spatial frequencies, as demonstrated by the spectrum of the difference of the Fourier spectra of different versions of the stimuli and by an inverse Fourier transform performed on the stimuli following a filtering of low spatial frequency components. These high spatial frequency components were not available to the visual system at contrast threshold, and as a consequence, the detection threshold was equivalent for these two types of stimuli. As mentioned in the introduction, some degree of identification is possible at detection threshold. Postexperimental reports of the subjects indicated that they could sometimes perceive the global shape of the stimuli (elongated or more round in form), but identification of the category of a stimulus (face, inverted face, or nonface) requires a higher level of contrast and a greater amount of physical information.

REFERENCES

Baron, J. (1978). The word superiority effect: Perceptual learning from reading. In W. K. Estes (Ed.), *Handbook of learning and cognitive processes* (Vol. 1, pp. 131-166). Hillsdale, NJ: Erlbaum.

Bonnet, C. (1989). La perception visuelle des formes. In C. Bonnet, R. Ghiglione, & J. F. Richard (Eds.), *Traité de psychologie cognitive: Vol. 1. Perception, action et langage* (pp. 2-82). Paris: Dunod.

Boucart, M., & Humphreys, G. W. (1990). Familiarity and nameability do not affect picture detection. *Bulletin of the Psychonomic Society*, **28**, 409-411..

Campbell, F. W., & Robson, J. G. (1968). Application of Fourier analysis to the visibility of gratings. *Journal of Physiology*, **197**, 551-566.

Doyle, J. R., & Leach, C. (1988). Word superiority in signal detection: Barely a glimpse yet reading nonetheless. *Cognitive Psychology*, **20**, 283-318.

Enns, J. T., & Gilani, A. B. (1988). Three-dimensionality and discriminability in the object-superiority effect. *Perception & Psychophysics*, **44**, 243-256.

Gorea, A., Demany, L., & Bonnet, C. (1986). Detection et identification en vision et en audition. *Bulletin de Psychologie*, **39**, 349-353.

Gorea, A., & Julesz, B. (1990). Context-superiority in a detection task line element stimuli: A low level effect. *Perception*, **19**, 5-16.

Homa, D., Haver, B., & Schwartz, T. (1976). Perceptability of schematic face stimuli: Evidence for a perceptual Gestalt. *Memory & Cognition*, **4**, 176-185.

McClelland, J. L., & Miller, J. (1979). Structural factors in figure perception. *Perception & Psychophysics*, **26**, 221-229.

Olzak, L. A., & Thomas, J. P. (1986). Seeing spatial patterns. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human performance: Vol. I. Sensory processes and perception* (pp. 7.1-7.56). New York: Wiley.

Purcell, D. G., & Stewart, A. L. (1986). The face-detection effect. *Bulletin of the Psychonomic Society*, **24**, 118-120.

Purcell, D. G., & Stewart, A. L. (1988). The face-detection effect: Configuration enhances detection. *Perception & Psychophysics*, **43**, 355-366.

Riddoch, M. J., & Humphreys, G. W. (1987). A case of integrative visual agnosia. *Brain*, **110**, 1431-1461.

Thomas, J. P. (1985). Detection and identification: How they are related. *Journal of the Optical Society of America*, **A2**, 1457-1467.

Tyler, C. W. (1987) Analysis of visual modulation sensitivity: III. Meridional variations in peripheral flicker sensitivity. *Journal of the Optical Society of America*, **A4**, 1612-1619.

van Santen, J. P. H., & Jonides, J. (1978). A replication of the face-superiority effect. *Bulletin of the Psychonomic Society*, **12**, 378-380.

Watson, A. B., & Robson, J. G. (1981). Discrimination at threshold: Labelled detectors in human vision. *Vision Research*, **21**, 1115-1122.

Weisstein, N., & Harris, C. S. (1974). Visual detection of line segments: An object-superiority effect. *Science*, **186**, 752-755.

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