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Attention and size in a global/local task

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Abstract

Two-letter stimuli, consisting of one small letter inside a much larger one (in Experiments 1A, 1B, and 2) or inside a "blob" (in Experiment 3), were used to examine the role of size difference in global/local tasks. The small letter was placed at locations that avoided contour interactions. The results showed no *identity interference*, in that the specific identity of the large letter did not differentially affect identification of the small one. However, there was evidence of *global advantage*, in that the *presence* of a large letter hindered identification of the small one. The magnitude of the global advantage effect, as measured by the difference in performance between the small-single and small-embedded conditions, was largest (about 200 ms reaction time (RT) difference) when the large letters were the same as the small ones, lower (a 63 ms difference in Experiment 1B, and 89 ms in Experiment 2) when the large letters were unrelated to the small ones, and lowest (a 25 ms difference) when the large stimuli were blobs. It is proposed that the amount of interference depends on the overlap between the features of the large stimuli, *as a set*, and those of the small ones, also as a set. © 2001 Elsevier Science B.V. All rights reserved.

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1. Introduction

A fundamental issue in perception concerns the allocation of attention to different objects in the visual field. Attention is deployed as a function of the number of objects, their size, shape, color, and other physical dimensions, their proximity, whether they are simple or complex, familiar or unfamiliar. Successful deployment of attention also depends on whether the location of a target is known or unknown, and whether the stimulus is presented for short or long durations.

Recently, research on attention has been restricted to the very early stages of processing, at exposures so brief that the stimulus disappears before eye movements are possible. One topic of interest has been spatial attention (e.g., Posner, Snyder & Davidson, 1980; Pylyshyn, 1994; Yantis, 1993; see review by Wright & Ward, 1988). A second has dealt with global/local issues stemming from Navon (1977). The research reported here used simplified stimuli to explore the role of size differences in global/local tasks.

In a seminal article Navon (1977) proposed that perceptual processing follows a mandatory global-to-local sequence. His stimuli were compound letters, that is, large (global) letters made of small (local) letters. Navon used only two letters, H and S, to generate four critical stimuli, hH, sS, hS, and sH. In this notation, hH is a large H made up of small h's, sS a large S made up of small s's, and so on. Stimuli hH and sS are *consistent* because the large and small letters are the same. Stimuli hS and sH are *conflicting* because the large and small letters are different. Two attention conditions were employed. In the *global* directed condition, participants were instructed to identify the large letter and disregard the small one. In the *local* directed condition, participants were instructed to identify the small letter and disregard the large one. The hypothesis was that the large letter would be identified faster (or earlier) than the local one. On this assumption, in the local directed condition, a large letter that was the same as the small one would facilitate identification of the latter, whereas a large letter that was different would interfere with it. However, in the global directed condition, the identity of the small letter would not matter. This reasoning led to the crucial prediction that, in the local directed condition, the small letter would be identified faster in consistent (hH and sS) as opposed to conflicting (sH or hS) stimuli, a prediction often referred to as asymmetric interference. However, we will refer to it here as *identity* interference because it is predicated on the large letter being identified before, or faster, than the small one. The results of Navon's (1977) Experiment 3 supported the prediction of identity interference.

Navon's (1977) interpretation, however, soon proved controversial (Grice, Canham & Boroughs, 1983; Hoffman, 1980; Kinchla & Wolfe, 1979; Martin, 1979; Pomerantz, 1983; Ward, 1982). The source of many difficulties resides in the fact that compound letters are made of a single small letter repeated at many *closely spaced* locations, an arrangement that introduces a number of confounding variables. It has been shown that performance is affected by sparsity (LaGasse, 1993; Martin, 1979), lateral masking (Podrouzek, Modigliani & Di Lollo, 1992), and overall visual angle (Kinchla & Wolfe, 1979). Additionally, performance is affected by eccentricity (Grice et al., 1983; Pomerantz, 1983), spatial uncertainty (Lamb & Robertson, 1988), stimulus degradation (Hoffman, 1980), exposure duration (Paquet & Merikle, 1984), prior attentional allocation (Ward, 1982), whether one or two compound letters are presented (Paquet & Merikle, 1988), and whether the global pattern is made of few large or many small elements (Kimchi & Palmer, 1982, 1985). The effects of these and other variables have been discussed by Kimchi (1992); Lasaga (1989), and Paquet (1991). Kimchi's (1992) conclusion is still apt: "The perceptual mechanisms underlying the perceptual structure of hierarchical patterns are yet to be determined" (p. 33).

Apart from the fact that close spacing may affect performance in a variety of ways, it is also the case that, in compound letters, the small and large letters are of very different sizes and that this difference in size is inherently confounded with level of globality (Kimchi, 1992; Navon, 1977, 1981a,b; Podrouzek et al., 1992). The effect of the size difference in global/local tasks has not been systematically investigated. Navon (1981a), in a replication of an earlier Experiment (Navon, 1977, Experiment 3), used a condition in which the stimulus consisted of a single small letter and found that reaction time (RT) to this stimulus was actually *faster* than to global letters in the global directed condition. Podrouzek et al. (1992) used *single small* and *single large* letters as controls. They found that accuracy was best in the single large letter control condition, next best in the global directed condition, followed by the single small letter control, and worst in the local directed control. In other studies, size was varied indirectly as a by-product of sparsity manipulations. In essence, the effect of the size difference, per se, is unknown. If the size difference interacts with variables associated with spacing, it is not surprising that results obtained with compound letters have been anything but consistent across studies (Kimchi, 1992; Lasaga, 1989; Paquet, 1991).

In order to eliminate the possible interaction between close spacing and size difference, the present work used stimuli that consisted of only *two* letters of very different sizes, displayed in a manner that avoided contour interactions. Under these conditions, the large letter should have a processing advantage for the same reasons that it would have it if it were a compound letter, namely, as a higher node in a hierarchical structure (Navon, 1977; Palmer, 1977). Although most investigators have assumed that hierarchical structure must be defined in terms of many small identical components being used to make up larger ones, this is not necessary. A stimulus consisting of only two constituents, one much larger than the other in a particular spatial relation can also be considered as possessing hierarchical structure. For example, Navon (1977) used a picture of the moon and a star (a large and a small object, respectively) to illustrate the concept of structural hierarchy. The advantage of stimuli consisting of only two letters of different sizes is that, if the small letter is carefully placed, contour interactions as found in compound letters are avoided and the effect of size, per se, can be assessed by using appropriate controls, namely, single small and single large letter conditions.

Theoretically, the large letter could affect identification of the small one in one of two ways. The large letter could produce identity interference, as discussed above, which depends on whether it is the same or different from the small one. Alternatively, it could have only a *global advantage*. In this case, it would be only the *presence* of the large letter that would matter, not its actual identity. Global advantage is further discussed below. The purpose of Experiment 1A was to test for identity interference and/or global advantage using stimuli as described above.

2. Experiment 1A

This experiment replicated the design of Navon's (1977) Experiment 3, except that, instead of compound letters, the stimuli consisted of only two letters, a small letter inside a much larger one. As in Navon (1977), only the letters H and S were used, generating four critical stimuli, hH, sS, sH, and hS. In the present context, hH refers to a small h inside a large H, and so on. As mentioned, the purpose of the present experiment was to test for identity interference and/or global advantage, using these stimuli. The test for identity interference requires a comparison between responses to consistent (hH and sS) as compared to conflicting (sH and hS) stimuli in the local directed condition. Responses to the former should be facilitated as compared to responses to the latter.

This experiment also tested for global advantage. As previously discussed, Navon's (1977) notion of identity interference was predicated on the assumption that the identity of the large letter would be extracted automatically before, or more quickly, than that of the small one. This assumption, however, neglects that identification of any object may not be a unitary process, but one that may require a number of separate and (at least partially) sequential stages (Uttal, 1988). For example, according to Uttal: "Logically the *presence* of the stimulus must be encoded and its presence signified phenomenologically in some way *before anything else can be done with it* (p. 13, emphasis added)". Accordingly, recognition would seem to be a later stage of processing. To quote Uttal again: "Recognition ... certainly requires detection and possibly requires discrimination ... *as prerequisite processing steps* (p. 15, emphasis added)". This does not mean that detection and identification are *strictly* sequential, in the sense that the former must be completed before the latter can begin, but only that that the former may begin before the latter (cf. Parasuraman, Richer & Beatty, 1982; see also Navon, 1981b). Thus, it would seem that the visual system would have to begin by detecting the presence of an object before it could recognize it. It is therefore possible that the large letter could have a processing advantage, and yet affect only an early detection stage of object processing, leading to global advantage without identity interference. Operationally, global advantage means that it would be easier to identify the small letter when presented in isolation then when embedded in a large letter, and that this effect would be independent of the identity of the large letter. In contrast, identification of the large letter would be equally easy regardless of whether it was presented in isolation or accompanied by a small letter. It follows that, in order to test for global advantage, one must always employ a single small and single large letter control, a procedure rarely used in global/local tasks. Navon's (1981a) finding, that RT to a single small letter was faster than to a single small (local) letter embedded in a large (global) one, is consistent with global advantage. However, the result must be taken cautiously since he used compound letters.

2.1. Method

2.1.1. Stimuli

The stimuli consisted of the letters H and S which could be either large or small. In control conditions, a single small or a single large letter was displayed. In the critical conditions, two letters, a small one inside a large one, were displayed. The large letters were 27 mm wide × 39 mm high, the small ones 3 mm wide × 3.5 mm high. The pixels composing letters were so packed that both small and large letters appeared solid. On any trial, the center of the large letter was randomly located on an imaginary circle centered at fixation and having a radius of 4.6° of visual angle. On trials in which two letters were displayed, the small letter was randomly located at one of four positions inside the large letter, namely, top left, top right, bottom left, and bottom right from the center of the large letter, as illustrated in Fig. 1. The contours of the small letter were at least 0.8° from the nearest contour of the large one, thus eliminating contour interactions (Wolford & Chambers, 1984). On trials in which single small letters were displayed, the letter appeared at the same locations where it would have appeared had a large letter been present. Letters were white on dark background. A mask consisting of a rectangle of random colored dots, 7.0 cm wide × 8.3 cm high, was also used.

2.1.2. Design

The design included four conditions. In the *small-single* condition, referred to as hs, a single small letter, h or s, was randomly displayed on each trial. The task was to

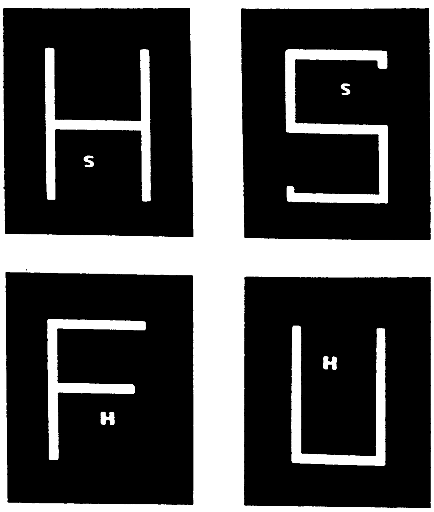

Fig. 1. Examples of stimuli used in Experiments 1A and 2. The small letter was randomly located at one of the four positions shown across the four stimuli.

identify the letter. In the *small-embedded* condition, referred to as hsHS, the display showed a small letter, h or s, inside a large one, H or S, and the task was to identify the small letter. This condition corresponds to the local directed attention condition in experiments with compound letters. In the *large-single* condition, referred to as HS, a single large letter, H or S, was randomly displayed on each trial, and the task was to identify the letter. In the *large-embedded* condition, referred to as HShs, the display again showed a small letter inside a large one. The task was to identify the large letter. This condition corresponds to the global directed attention condition in experiments with compound letters. These conditions conform to a 2×2 design in which one factor refers to direction of attention (whether attention is directed to the small or large letter), the other to embeddedness (whether the to-be-identified letter appears singly or is embedded in another). Within the embedded conditions, 2 stimuli (hH and sS) were consistent and 2 (hS and sH) were conflicting. All conditions were within-subject.

2.1.3. Apparatus and procedure

All events were controlled by an IBM-compatible 486-66 Mhz computer system that included an ATI video card and a 15 in. noninterlaced color monitor. Screen resolution was 640×480 pixels/in. A 256 color palette was used in VGA mode. All experimental events were under the control of a program written by one of the authors (SG).

A trial began with a fixation cross displayed at the center of the screen for 500 ms. This was followed by a stimulus displayed for 40 ms. The stimulus was followed by the mask which remained visible until a response was made. These parameters are the same as those used by Navon (1977), and were adopted so as to keep our procedure as similar to his as possible. The next trial began 2.5 s after the response. Both accuracy and RT were recorded. Conditions were presented in counterbalanced orders in two separate sessions. Each session comprised four blocks of trials, one block per condition. Each block consisted of 48 trials, the first 12 of which were counted as practice and not analyzed. Blocks were separated by 20 s to permit a rest. In single letter conditions, each letter appeared an equal number of times in random order. In embedded conditions, each of the four stimuli, hH, sS, hS, and sH, appeared an equal number of times in random order in each block. Participants were run individually. They sat in front of the screen, their head held by a chin rest maintaining a viewing distance of 57 cm. Responses were made by depressing the keys < or > on the keyboard, which were labeled H and S, respectively. All responses were made with the index or middle finger. One half of the participants used their left hand and the other half their right hand to respond. Response hand was counterbalanced for right and left handers. Participants were instructed to respond as quickly and as accurately as possible.

2.1.4. Participants

The participants were 6 male and 6 female undergraduate students (mean age = 22 years; range = 18–27 years) who received course credit for their participation. All had normal or corrected-to-normal vision.

2.2. Results

Preliminary analyses indicated that performance improved from session 1 to session 2, but did not interact with any other variable. Therefore, the following results are reported for both sessions combined.

2.2.1. Accuracy

Response accuracy was generally high. Mean correct responses were 96%, 83%, 98%, and 96% in the small-single (hs), small-embedded (hsHS), large-single (HS), and large-embedded (HShs) conditions, respectively. Individual comparisons showed that accuracy in the small-embedded condition was significantly lower than in all other conditions combined, $F(1, 11) = 30.17, P < 0.01$. The latter did not differ from one another, all being at ceiling, $F(2, 22) = 0.25, P > 0.10$.

2.2.2. Identity interference

In order to determine identity interference, only responses to the small letters in the small-embedded condition were examined. Mean correct responses to the consistent stimuli, hH and sS, were 90% and 63%, respectively, for a combined mean of 76%. Mean correct responses to the conflicting stimuli, hS and sH, were 93% and 88%, respectively, for a combined mean of 90%. Since the data were in the direction opposite that expected for identity interference, no statistical analyses were carried out. It may be noted that the least accurate performance occurred to a consistent stimulus (sS).

2.2.3. Reaction time

Each participant's median RT on correct responses was calculated for each condition, and the following are means of individual medians. RT was slowest in the small-embedded conditions ($M = 619$ ms), much faster in the small-single condition ($M = 446$ ms), and fastest in the large-single and large-embedded conditions ($M = 372$ and 373 ms, respectively). A 2(attention: directed to small or large letters) $\times$ 2(embeddedness: letters presented singly or embedded) analysis of variance (ANOVA) yielded a main effect of attention, $F(1, 11) = 92.35$, $P < 0.001$, as well as a main effect of embeddedness, $F(1, 11) = 27.23, P < 0.001$. More importantly, The attention $\times$ embeddedness interaction was highly significant, $F(1, 11) = 28.46, P < 0.001$. The interaction was due to the fact that in the large-single and large-embedded conditions RTs were essentially identical, whereas RT in the small-single condition was significantly faster than in the small-embedded condition. RT in the small-single condition was slower than in both large conditions combined, $F(1, 11) = 34.93, P < 0.001$.

2.2.4. Identity interference

In order to determine identity interference, only responses to the small letters in the small-embedded condition were examined. Mean RTs to the consistent stimuli, hH and sS, were 597 and 695 ms, respectively, for an overall mean of 646 ms; mean RTs to the conflicting ones, hS and sH, were 620 and 649 ms, respectively, for an overall mean of 635 ms. Since the data were in the direction opposite that expected for identity interference, no statistical analyses were carried out. It may be noted that the slowest RT occurred in response to a consistent stimulus (sS).

2.3. Discussion

In this experiment, accuracy was generally high. Nevertheless small but significant differences were found across conditions. Importantly, the pattern of the accuracy data mirrored that of the RT data, indicating no speed-accuracy trade off. Thus, the accuracy data provide the same kind of information as the RT data.

The main findings of this experiment were that: (i) There was no identity interference. On the contrary, performance in the small-embedded condition was worst in response to a *consistent* stimulus. (ii) Performance in the small-single condition was much better (RT was about 200 ms faster) than in the small-embedded condition, suggesting that the *presence* of a large letter made the identification of the small one difficult. On the other hand, the presence of the small letter did not affect identification of the large one. This pattern suggests global advantage. (iii) Finally, in the small-single condition, RT was 78 ms slower than in the large-single condition, suggesting that, in the present experiment, absolute size also affected performance (cf. Shultz & Eriksen, 1978).

One of the results of the present experiment was that performance in response to stimulus sS was very much worse than that to any other stimulus. The reason for this is not obvious. However, in this kind of task, it is not unusual for performance to depend on the particular *pair* of letters used to make up the stimulus. In a thorough analysis of letter pairs effects, Lamb and Robertson (1988) found that the pattern of results they obtained was strongly dependent on the pair of letters involved (see also Lamb & Yund, 1993, 1996a). Unfortunately, effects such as these are rarely reported (Lamb & Robertson, 1988, p. 176). One possible explanation of letter pair effects is that particular pairs may give rise to unintended configural features (Kimchi, 1992, 1994) and these, rather than those intended by the experimenter, may be responsible for observed results. Another possibility is to appeal to feature interactions, as discussed below. In general, although letter pair interactions are common (Lamb & Robertson, 1988), they are at present poorly understood.

3. Experiment 1B

The results of Experiment 1A suggest that, when identifying the small letter, the identity of the large letter did not matter but its presence did. If this is true, it is possible that *any* large letter would affect the identification of the small one in the same way. The purpose of Experiment 1B was to test this hypothesis by using U and F, instead of H and S, as large letters.

3.1. Method

The method was identical to that of Experiment 1A, except that the large letters were U and F. The small letters were the same as in Experiment 1A. Thus, in the small-single and small-embedded conditions, the task was to identify whether the small letter was h or s. In the large-single and large-embedded conditions, the task was to identify whether the large letter was U or F. The participants were 8 female undergraduate student volunteers (mean age = 22 years; range = 17–31 years), none of whom had participated in Experiment 1A. All had normal or corrected-to-normal vision.

3.2. Results

As in Experiment 1A, performance improved from session 1 to session 2, but session did not interact with other variables.

3.2.1. Accuracy

Accuracy was very high throughout, being 96% correct or better. No analyses were therefore carried out on this measure.

3.2.2. Reaction time

RT was slowest in the small-embedded conditions ($M = 534$ ms), faster in the small-single condition ($M = 467$ ms), and fastest in the large-single and large-embedded conditions ($M = 379$ and 380 ms, respectively). A 2(attention: directed to the small or large letter) × 2(embeddedness: letters presented singly or embedded) ANOVA yielded a main effect of attention, $F(1,7) = 51.81, P < 0.001$, as well as a main effect of embeddedness, $F(1,7) = 29.93, P < 0.001$. The attention × embeddedness interaction was also significant, $F(1,7) = 12.96, P < 0.01$. The interaction was due to the fact that in the large-single and large-embedded conditions RTs were essentially identical, whereas RT in the small-single condition was significantly faster than in the small-embedded condition. RT in the small-single condition was slower than in both large conditions combined, $F(1,7) = 33.87$, $P < 0.001$.

3.3. Discussion

The RT results of this experiment mirrored those of Experiment 1A. RT was slowest in the small-embedded condition, faster in the small-single condition, and fastest in the large-single and large-embedded conditions, which did not differ. This pattern indicates that the presence of the large U and F interfered with the identification of the small letters inside them. However, whereas in Experiment 1A the difference between the small-single and small-embedded conditions was about 200 ms, in the present experiment the corresponding difference was only about 65 ms. This suggests that if the large letters belong to the same set of stimuli as the small ones (i.e., H and S) they interfere more than if they belong to a different set (i.e., U and F). However, this conclusion is based on results obtained in separate experiments. The purpose of Experiment 2 was to compare in a single experiment all conditions of Experiments 1A and 1B.

4. Experiment 2

Experiment 2 included 7 conditions, namely, hs (small single h or s), HS (large single H or S), UF (large single U or F), hsHS (small h or s embedded in a large H or S), hsUF (small h or s embedded in a large U or F), HShs (large H or S with a small h or s embedded in it), and UFhs (large U or F with a small h or s embedded in it). In this notation, the size of the first letters indicates the direction of attention, that is, whether small or large letters are to be reported. The type of large letters indicates whether they were from the same set as the small ones (H and S), or a different set (U and F). For example, condition hsUF means that attention was directed to small h or s embedded in large U or F letters.

4.1. Method

Stimuli, apparatus and procedure were identical to those of the previous experiments. There were again two sessions in each of which all conditions were presented in counterbalanced orders. The design was complete within-subjects. Because the experiment was twice as long as the previous ones, a 10 min break was given between session 1 and session 2. The participants were 11 female and 5 male undergraduates (mean age = 20.1 years; range = 17–28 years) who participated for course credit. None had participated in Experiments 1A or 1B, and all had normal or corrected-to-normal vision.

4.2. Results

4.2.1. Accuracy

A 7(condition: hs, hsHS, hsUF, UF, HS, UFhs, and HShs) $\times$ 2(session: 1, 2) ANOVA, both factors within-subjects, yielded a main effect for condition, $F(6,90) = 34.09, P < 0.01$, a main effect for session, $F(1,15) = 7.14, P < 0.05$, and a significant interaction, $F(1,90) = 4.10, P < 0.05$. The interaction was due to the fact that performance improved from session 1 to session 2 in conditions hsHS (from 79% to 86%) and in condition hsUF (from 88% to 95%) conditions. In all other conditions, performance was at ceiling (96% or better) in both sessions.

4.2.2. Identity interference

In order to determine identity interference, responses to the 4 stimuli within the hsHS condition were examined in detail for both sessions combined. Mean correct responses to the consistent stimuli, hH and sS, were 93% and 63%, respectively, for a combined mean of 78%. Mean correct responses to the conflicting stimuli, hS and sH, were 94% and 85%, respectively, for a combined mean of 90%. Since the data were in the direction opposite to that expected for identity interference, no statistical analyses were carried out. It may be noted that the least accurate performance occurred to a consistent stimulus (sS).

4.2.3. Reaction time

Mean RTs are shown in Fig. 2. A 7(condition: hs, hsHS, hsUF, UF, HS, UFhs, and HShs) × 2(session: 1, 2) ANOVA, with repeated measures on both factors, yielded a main effect for condition, $F(6,90) = 66.37, P < 0.01$, a main effect for session, $F(1,15) = 37.76, P < 0.001$, and a significant interaction, $F(6,90) = 3.53$, $P < 0.01$. As can be seen in Fig. 2, the interaction was due to the fact that performance in conditions hsHS and hsUF improved much more from session 1 to session 2 than in all other conditions. Although it is clear from Fig. 2 that the pattern of results was the same in both sessions, the following analyses examined each session separately.

A one-way ANOVA, comparing the 7 conditions at session 1, yielded an overall highly significant effect, $F(6,90) = 34.78, P < 0.01$. Subsequent comparisons showed that (a) condition hsHS ($M = 702$ ms) was significantly slower than condition hsUF ($M = 593$ ms), $F(1,15) = 7.86, P < 0.02$; (b) condition hsUF was significantly slower than condition hs ($M = 506$ ms), $F(1,15) = 12.90, P < 0.01$; (c) condition hs was significantly slower than all large conditions combined ($M = 426$ ms), $F(1,15) = 24.30, P < 0.01$; and, finally, (d) none of the latter (UF, HS, UFhs, and HShs) differed from one another, $F(3,45) = 2.16, P > 0.10$.

A second one-way ANOVA compared all 7 conditions at session 2, yielding an overall highly significant effect, $F(6,90) = 48.11, P < 0.01$. Subsequent comparisons

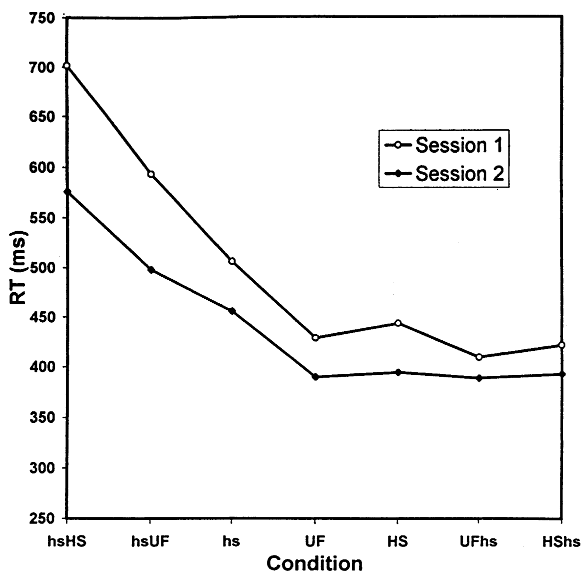

Fig. 2. Mean RT as a function of condition and session in Experiment 2.

showed that (a) condition hsHS ($M = 576$ ms) was significantly slower than condition hsUF ($M = 499$ ms), $F(1,15) = 35.86, P < 0.01$; (b) condition hsUF was significantly slower than condition hs ($M = 456$ ms), $F(1,15) = 5.47, P < 0.05$; (c) condition hs was significantly slower than all large conditions combined ($M = 392$ ms), $F(1,15) = 42.79, P < 0.01$; and, finally, (d) none of the latter (UF, HS, UFhs, and HShs) differed from one another, $F(3,45) = 0.12, P > 0.10$.

4.2.4. Identity interference

In order to determine identity interference, only responses to the small letters within condition hsHS were examined in detail for both sessions combined. Mean RTs to consistent stimuli, hH and sS, were 613 and 711 ms, respectively, for a combined mean of 662 ms. Mean RTs to conflicting stimuli, hS and sH, were 615 and 688 ms, respectively, for a combined mean of 652 ms. Since the data were in the direction opposite to that expected for identity interference, no statistical analyses were carried out. It may be noted that the slowest performance occurred to a consistent stimulus (sS). This pattern mirrors that obtained with the accuracy data.

4.2.5. Discussion

The results of this experiment were identical to those of Experiments 1A and 1B combined. (i) There was no evidence of identity interference. On the contrary, as in Experiment 1A, performance in the small-embedded condition was worst in response to a consistent stimulus (sS). (ii) Performance was uniformly high in all large conditions (UF, HS, UFhs, and HShs). This, in conjunction with the fact that performance in the small-single condition (hs) was worse than in the small-embedded conditions (hsUF and hsUS), strongly suggests global advantage. (iii) The large difference in RT between conditions hsHS and hsUF replicates the results of Experiment 1B, and implicates the existence of a set effect.

5. Discussion of Experiments 1A, 1B, and 2

Most studies of global/local issues have used compound letters as the stimuli of choice. Compound letters are seen as ideal because they appear to contain only two pieces of information, one global (the large letter), the other local (the small letter) (Navon, 1977). Although this appears to be logically true, it neglects that close packing of the local letters introduces a number of factors, many of them related to contour interactions, whose effect on performance renders interpretation difficult, especially in the local directed condition. The stimuli used in the present experiments consisted of only one small and one large letter, the former placed inside the latter at locations that avoided contour interactions. The results bear on 3 issues, namely, identity interference, global advantage, and set interference.

5.1. Identity interference

Navon's (1977) hypothesis of identity interference was predicated on the assumption that the large letter is identified before (or earlier) than the small one, and that its identity would facilitate (in consistent stimuli) or hinder (in conflicting stimuli) identification of the small one. The results of the present Experiments 1A and 2 provided no evidence of identity interference. If anything, evidence to the contrary was obtained. Identity interference has been difficult to prove conclusively in research with compound letters (Kimchi, 1992; Lasaga, 1989; Paquet, 1991). The present results, obtained with stimuli that avoid contour interactions, cast considerable doubt on its existence.

5.2. Global advantage

Although the identity of the large letter did not matter, its presence did, providing strong evidence for global advantage. Global advantage is demonstrated if performance in the small-embedded condition is worse than that in the small-single condition, but performance in the large-embedded condition is the same as that in the large-single condition. This pattern was evident in all experiments, and is consistent with results of studies with compound letters in which the appropriate controls (small-single and large-single conditions) are employed (e.g., Lamb & Robertson, 1988; Navon & Norman, 1983; Podrouzek et al., 1992). The present findings, obtained with stimuli that avoided contour interactions, suggest that global advantage is a robust phenomenon and that the main factor responsible for it is the size difference between small and large letters (cf. Navon & Norman, 1983).

What causes global advantage? It has been suggested that global advantage could result from a purely sensory mechanism, to wit, low spatial frequencies being processed faster than high ones (e.g., Badcock, Whitworth, Badcock & Lovegrove, 1990; Hughes, Fendrich & Reuter-Lorenz, 1990; Navon, 1991; Robertson, 1996; Sergent, 1987; Shulman, Sullovan, Gish & Sakoda, 1986). However, recent research using contrast balanced stimuli suggests a minor role, if any, for spatial frequency (Lamb & Yund, 1996a,b; Lamb, Yund & Pond, 1999; see also Hübner, 1997). In this context, the set interference effect discussed below strongly suggests a cognitive, top-down component because, if global advantage was entirely due to a sensory mechanism, then the particular large letters employed would not matter at all.

5.3. Set interference

One of the most interesting findings of the present research was that the degree of global advantage depended on the type of large letter used. It is not obvious what mechanism could be responsible for this effect. It cannot be one that runs all the way to complete identification of the large letter, since identity interference was not obtained, nor one that stops at the (large letter) earliest detection stage, with no further processing, since this would not produce a set effect. Therefore, it must act at some intermediate level, most likely that of feature analysis. It is possible that feature interference might operate at such a level. Bjork and Murray (1977) obtained the counterintuitive result that it was more difficult to identify a letter when it was accompanied by a copy of itself (i.e., two identical letters were displayed; cf. stimuli sS and hH here) than when presented in isolation, or when accompanied by other letters (see also Santee & Egeth, 1980). Bjork and Murray (1977) attributed this finding to feature inhibition. Later Santee and Egeth (1982) showed that the effect could be obtained only when the stimulus was followed by a mask, a situation similar to that of the present investigation. In the above studies the target and interfering letters were of the same size. In the present study, one letter was much larger than the other. Therefore, due to global advantage, feature interference should be even more pronounced.

Feature interference could account for the set effect if it is assumed that, in the local directed condition, either one of the large letters would activate not just its own features, but the *set* of features associated with *both* (large) letters, and that this activation would interfere with the analysis of the small letter. The amount of interference would then be a function of the overlap between the set of features associated with the large letters, *as a set*, and the set of features associated with the small ones. This interpretation would account for the fact that U and F were less interfering than H and S.

If the above explanation is correct, it suggests that the degree of global advantage could be reduced further, relative to that produced by the letters U and F, if the set of features associated with the large stimuli had minimal overlap with those of the small letters. Experiment 3 tested this hypothesis.

6. Experiment 3

In this experiment, the large stimuli were "blobs" that would appear to have few, if any, features in common with those of the letters inside them. Therefore, according to the feature interference hypothesis, the global advantage associated with these stimuli should be further reduced relative to that obtained with the letter stimuli U and F.

6.1. Method

The stimuli are shown in Fig. 3. The apparatus and procedure were identical to those of the previous experiments. In the small-single and small-embedded conditions, participants identified whether the small letter was h or s. In the large-single and large-embedded conditions, participants identified which blob was present (pictures of each blob were placed next to the appropriate keys). The participants were 7 males and 5 female graduate students (mean age = 29 years; range = 23–41 years) who volunteered for the experiment. All had normal or corrected-to-normal vision.

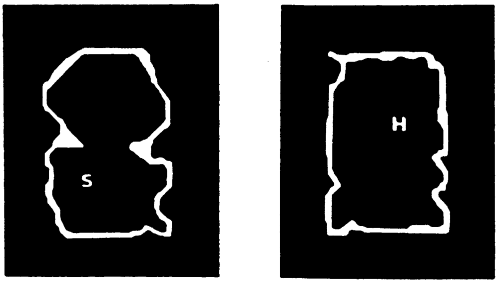

Fig. 3. Examples of stimuli used in Experiment 3.

6.2. Results and discussion

The purpose of this experiment was to compare the small-single condition with the small-embedded condition in which the small letter was embedded in blobs. On accuracy, percent correct were 96.6 and 93.7 for the small-single and small-embedded conditions, respectively, this difference being significant, $t(11) = 2.28, P < 0.05$. On RT, mean RTs were 527 and 552 ms for the small-single and small-embedded conditions, respectively, this difference also being significant, $t(11) = 2.75, P < 0.05$. Further analyses revealed no other significant differences. These results show that the presence of the blobs interfered with the identification of the small letter, but the amount of interference was less than that found with U and F in the previous experiments.

7. Conclusion

Overall, the results showed no evidence of identity interference. However, they did demonstrate a global advantage effect. The magnitude of this effect, as measured by the difference in performance between the small-embedded and small-single conditions, was largest (about 200 ms RT difference) when the large stimuli were the same letters as the small ones, lower (a 63 ms difference in Experiment 1B, and 89 ms in Experiment 2) when the large stimuli were letters unrelated to the small ones, and lowest (a 25 ms difference) when the large stimuli were blobs. These differences constitute what we have referred to as set interference, suggesting that the amount of interference depends on the overlap between the features of the large stimuli, as a set, and those of the small ones, also as a set.

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