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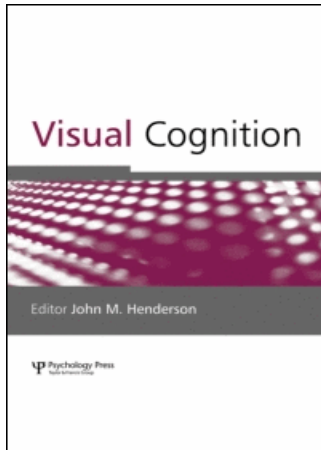
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Visual memory for shape-colour conjunctions utilizes structural descriptions of letter shape

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Visual memory for shape–colour conjunctions utilizes structural descriptions of letter shape

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Visual recognition memory for shape–colour associations is superior when the colours were originally perceived to belong to the shapes, rather than to the backgrounds against which the shapes appeared. Recognition is at chance in the latter case. In two experiments, the nature of the shape representations supporting visual memory for shape–colour conjunctions is examined. Letters are used as to-be-remembered shapes and the impact of two types of change in their appearance as recognition probes is assessed. When letters reappear in the same case, recognition performance is unaffected by a change in font (Experiment 1). However, when letters reappear in the same font, recognition performance drops to chance if letter case is changed (Experiment 2). The contrast between these two types of change was not confounded with differences in the visual similarity of the memory and probe letters. It seems that colour is linked to structural descriptions of letter shape in visual memory. The relationship between these descriptions and other forms of representation, including abstract representations of letter identity, is discussed.

Walker and Cuthbert (1998) provide evidence that visual memory for shape–colour associations can be object based. They presented participants with a series of visual items, each comprising a shape and a colour. For some items, the shape was coloured and appeared on a white background (a *unitary* display). For other items, the shape was white and appeared on a coloured background (a *separate* display). Although in both conditions shape was defined by a colour–white boundary, only in the unitary condition did shape and colour belong to the same object. Participants were required to remember which colour appeared with which shape. In most of the experiments, memory was tested with a four-alternative forced-choice recognition test. Each recognition test display depicted

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the same probe shape in association with two colours, the correct one and a foil, in both a unitary and a separate arrangement. Participants had to decide which of the four alternatives had appeared in the original memory list.

Walker and Cuthbert (1998) were concerned to dissociate the contributions of visual and verbal representations to the recognition of shape–colour associations. They did this in a number of ways, including: Comparing performance with nameable and non-nameable shapes, comparing performance with and without articulatory suppression, and denying a role for all nonvisual representational forms by creating sets of shapes based on a single letter of the alphabet. The same pattern of results was observed regardless of the manner in which the availability of verbal representations was controlled. When participants had no option but to rely on visual memory representations, their recognition of shape–colour associations was superior for unitary displays than for separate displays (referred to as the *unitization effect*, see Asch, Ceraso, & Heimer, 1960; Ceraso, 1985, 1990; Wilton, 1989). Indeed, performance was no higher than chance with separate displays. When participants were allowed to verbally recode the items, the unitization effect did not arise, because memory for separate displays was enhanced to levels equivalent to those observed with unitary displays. It was concluded that, in the absence of verbal recoding, memory for shape–colour associations is mediated by visual representations that are object based, with only those conjunctions of features emanating from the same object being represented. In contrast, when verbal representations support memory for shape–colour associations, there seems to be no barrier to the representation of combinations of features that cross object boundaries. As a result, a unitization effect is not observed. These results indicate that a unitization effect can be taken as evidence that memory for shape–colour associations is being mediated by visual representations that are object based. These representations preserve information about visual features that are associated because they belong to the same object, rather than because their appearance was temporally or spatially contiguous. The object-based nature of the visual representations is even more apparent when shape–colour memory is at chance for separate displays.

The two experiments reported here examined the nature of the visual representation of shape supporting memory for shape–colour conjunctions. More specifically, it was asked if it preserves all the surface details of the shape of a stimulus (as if it were a pictorial representation), or only some abstracted visuospatial features (such as would be captured by a structural description). Individual letters of the alphabet were the to-be-remembered shapes. This allowed alternative visual instantiations of each stimulus to share a common underlying structure, or to be structurally different. Consider, for example, the alternative instantiations of a letter created by varying the font from which a particular case version is drawn (e.g., an uppercase *A* in a variety of display fonts). Despite the possibility of marked variations in surface form, these

instantiations will share an underlying structure that allows them all to be identified as a particular case version of the same letter of the alphabet. Alternatively, the uppercase and lowercase versions of at least some letters of the alphabet (e.g., *Aa*, *Rr*, *Nn*, *Ee*, and *Gg*) have quite different underlying structures, even when they are drawn from the same font.

The experiments assessed the sensitivity of shape-colour memory to changes in the visual appearance of the memory letters when they reappear as recognition probes. In the first experiment, the recognition displays incorporated visually identical replicas of the memory letters, or same-case/different-font versions of the letters. The second experiment focused on letters of the alphabet that are structurally dissimilar in their uppercase and lowercase forms, and the recognition displays incorporated visually identical replicas of the memory letters, or different-case/same-font versions of these. Assuming that the shape of a letter is represented in memory in terms of its underlying structure, rather than in terms of its surface form, it was predicted that a unitization effect would be observed with both visually identical and same-case/different-font probe letters (Experiment 1), but not with different-case/same-font probe letters (Experiment 2).

EXPERIMENT 1

If the visual representation of shape that is linked with colour describes only the underlying structure of a letter, then a unitization effect should occur whenever a recognition probe retains this structure. In Experiment 1, the to-be-remembered shapes were uppercase and lowercase letters appearing in a variety of display fonts. When the letters reappeared as probes, they either retained their case and font (and hence were visually identical in shape) or they retained their case but appeared in a different font (and hence preserved only the underlying structure of the letter). In either situation, a unitization effect was expected to emerge, provided the involvement of verbal memory was precluded by requiring participants to suppress any relevant articulation during the study phase of the task (see Baddeley, 1990, for a review of the functional significance of articulation in the derivation of verbal memory representations of visual stimuli, and see Schiano & Watkins, 1981, and Hitch, Woodin, & Baker, 1989, for demonstrations of the effectiveness of articulatory suppression as a means of preventing this from happening).

Method

Participants. Eighty students attending either Bolton Institute or South Trafford College participated in the experiment. Twenty participants were randomly assigned to each of the four conditions created by crossing articulatory suppression (i.e., with vs. without suppression) with probe type (i.e., same font probe vs. different font probe).

Materials. The memory items were created by cutting letter shapes out of card and pasting them on to rectangular cards measuring 10×6 cm. The overall dimensions of the letters averaged approximately 6×4 cm. For unitary displays, each letter was cut out of coloured card and pasted on a white card. For separate displays, each letter was cut out of white card and pasted on a coloured card. The display fonts used to generate the letter shapes were selected from the 1981 Letraset catalogue and were: American Uncial, Baby Teeth, Countdown, Croissant, Davida, Egyptienne Bold, Fraktur Bold, Futura Demibold Script, Kalligraphia, Motter Ombra, Old English, Stilla Caps, Stop, and Traffic. These fonts can be viewed on various Web sites, including www.myfonts.com. The fonts were chosen to ensure that each selected letter of the alphabet could appear in two distinctive forms, so that the same-case/different-font versions of a letter could be as visually dissimilar to each other as the different-case/same-font versions (see the supplementary observations reported below for confirmation that the levels of visual similarity were matched in this way). Despite their rather unusual and distinctive appearance, however, the identity (and case) of each letter could be appreciated, even when it was seen in isolation.

Four packs of 12 cards were created. All four packs used the same letters of the alphabet, which were: A, B, D, E, F, G, N, Q, T, W, X, and Z. For two packs, a particular font was selected for each individual letter with the restriction that the same font was not used for more than two letters. For the other two packs, a new font was assigned to each letter. Each pack contained six unitary and six separate letter-colour combinations. Across the packs of cards each letter appeared twice in a unitary display and twice in a separate display. Six colours (red, blue, green, yellow, orange, and pink) were assigned randomly to the letters, independently for each pack of cards. Each colour appeared once in a unitary display and once in a separate display in every pack of cards.

The recognition test cards measured 21×15 cm, and had four smaller cards measuring 10×6 cm pasted on them. All four of these small cards incorporated exactly the same letter shape. For two of them, the letter shape appeared with the same colour as in the study phase, once in a unitary arrangement and once in a separate arrangement. For the other two cards, the letter shape appeared with a different colour, again in both a unitary and a separate arrangement. In relation to each pack of cards, every colour served as a foil in a unitary and a separate condition, and was paired with a correct colour on a random basis. In one condition, the letter shapes on the recognition cards were identical to the shapes that had been encountered in the study phase (i.e., same-case/same-font). In a second condition, the letter shapes on the recognition cards were same-case/different-font versions of the studied letter shapes. For this condition, all of the probe letter shapes were based on Frankfurter Medium, a display font that emphasizes the essential (prototypical) structure of each letter, and which is

devoid of the incidental visual features that give other display fonts their distinctive appearance.

Procedure. In an initial familiarization phase, participants were shown black-on-white outline drawings of the letters, in the display fonts in which they would later appear. This was done to confirm that the letters could be recognized correctly when seen in isolation. After this familiarization phase, each participant completed a single trial. In the nonsuppression condition, no restrictions were imposed on participants' articulation, so they were free to verbally recode the stimuli. In the suppression condition, participants were required to repeatedly utter the word "the", at an audible level and without pausing, starting just before the first memory stimulus was presented, and ending with the presentation of the first recognition test display. In each of the four conditions obtained by crossing suppression with probe type, an equal number of participants were presented with each of the four packs of cards. It was explained that a series of cards would be presented, and that each card comprised a letter shape and a colour. Their task was to remember which letter shapes and colours appeared together. Explicit instruction was given that the colour to be associated with each shape was never white, but rather the other colour, regardless of whether it was the cut-out letter shape, or the larger card on which this was pasted, that was coloured. Participants inspected each card for 5 s in a random order. Immediately afterwards, the recognition test cards were presented in a random order. Participants were asked to indicate which of the four probe cards matched a card appearing in the memory set. There were no restrictions on the time allowed to arrive at each decision and participants were instructed to guess if necessary.

Results

Table 1 gives the mean percentage correct colour recognition for the various conditions, scored without regard to whether the nature of the shape-colour association (unitary vs. separate) was also correctly recognized.¹ Analysis of variance (ANOVA) was undertaken on the number of correct responses, with suppression (with vs. without suppression) and probe type (same font vs. different font) as between-participants factors, and unitariness (unitary vs. separate displays) as a within-participants factor. The main effects of suppression and unitariness were both significant: $F(1, 76) = 9.28$, $MSE = 1.55$, $p = .003$, and $F(1, 76) = 13.38$, $MSE = 0.90$, $p = .0005$, respectively. The main effect of

¹In both experiments reported here the pattern of results was the same when correct colour recognition was made contingent on participants also correctly remembering whether the shape-colour combination was unitary or separate.

TABLE 1
 Experiment 1: Percentage correct recognition of colour associated with same-font probes and different-font probes for same-case letter shapes memorized under conditions of articulatory suppression and nonsuppression

| | <i>Unitary</i> | <i>Separate</i> |
|----------------------------------|----------------|-----------------|
| With articulatory suppression | | |
| Same-font probes | 63.3 | 48.3 |
| Different-font probes | 61.7 | 50.0 |
| Without articulatory suppression | | |
| Same-font probes | 69.2 | 61.7 |
| Different-font probes | 67.5 | 65.0 |

probe type was not significant, $F < 1$, and this factor did not interact significantly with any other factor, all $F < 1$. The overall interaction between suppression and unitariness was marginally significant, $F(1, 76) = 2.76$, $MSE = 0.90$, $p = .10$. Planned analysis of simple effects confirmed that, although the effect of unitariness was not significant when relevant articulation was allowed, $F(1, 76) = 1.99$, $MSE = 0.90$, $p = .16$, it was significant when relevant articulation was suppressed, $F(1, 76) = 14.15$, $MSE = 0.90$, $p < .001$. Suppression had a significantly deleterious effect on memory for separate displays, $F(1, 76) = 11.23$, $MSE = 1.29$, $p = .001$, but had no significant impact on memory for unitary displays, $F(1, 76) = 2.09$, $MSE = 1.17$, $p = .15$. Comparison of the observed number of correct responses against the number expected by chance confirmed that, in the absence of the opportunity for verbal recoding, there was no memory for the shape-colour associations in the separate displays. Thus, with suppression, the observed level of recognition, when collapsed across probe type, was significantly higher than chance for unitary displays, but not for separate displays: $t(39) = 4.39$, $SD = 1.08$, $p < .001$, and $t(39) = -0.29$, $SD = 1.08$, $p > .10$, respectively. Without suppression, however, the level of recognition was significantly higher than chance for both unitary and separate displays: $t(39) = 6.58$, $SD = 1.06$, $p < .001$, and $t(39) = 4.37$, $SD = 1.16$, $p < .001$, respectively.

Discussion

The results confirm the impact of verbal recoding on the unitization effect (see Walker & Cuthbert, 1998). Whereas a unitization effect for shape-colour associations was observed when verbal recoding was precluded, it was not observed when verbal recoding was permitted. The absence of a unitization effect with verbal recoding can again be attributed to the enhanced recognition of shape-colour associations from separate displays. The results confirm that a

unitization effect is indicative of a contribution from visual, rather than verbal, memory representations that are object based.

Changing the font in which a letter reappeared as a recognition probe had no significant impact on shape-colour memory. It seems clear, therefore, that the unitization effect is not contingent on probing memory with a shape that is identical to the memory stimulus. Rather, the probe needs only to preserve the underlying structure of the memory stimulus. This indicates that the visual representation of shape supporting shape-colour memory is a structural description that embraces the defining characteristics of a letter in a particular case. Visual features that are incidental to this description, and that are the focus of attention when typographers design a font, are not incorporated in the representation.

Before this conclusion is accepted, it is necessary to examine two alternative interpretations of the results. Although verbal recoding of the letter shapes was made difficult by articulatory suppression, and although Walker and Cuthbert (1998) provide a body of evidence to indicate that a unitization effect is contingent on the utilization of visual representations, it remains possible that recognition with the different-font probes in the suppressed/unitary condition was mediated by representations of letter names, or by abstract (i.e., nonvisual, nonverbal) representations of letter identities (see Rapp, Folk, & Tainturier, 2001, for a recent review of evidence for the abstract representation of letter identities). Experiment 2 tested these alternative explanations.

EXPERIMENT 2

If participants in the suppression condition of Experiment 1 were linking colour either to letter names, or to the abstract identities of the letters, then it should not matter whether probe letters share their underlying structure with the memory letters. The probe letters would only need to preserve the names or abstract identities of the memory letters. Experiment 2 assessed these possibilities by focusing on letters of the alphabet that are structurally dissimilar in their uppercase and lowercase forms, and by using different-case/same-font letter probes. If the unitization effect observed in Experiment 1 reflects memory either for the names of the letters, or for their abstract identities, then the effect should also be observed with different-case probes. If, however, the effect observed in Experiment 1 reflects visual representations of underlying letter structure, then it should not be observed with different-case probes. Finally, for direct comparison, a condition was again included involving visually identical probes, with the expectation that, as in Experiment 1, these would yield a unitization effect. In both conditions, the involvement of verbal memory was precluded by requiring participants to suppress any relevant articulation during the study phase.

Method

Participants. Thirty-eight students attending Bolton Institute participated in the experiment. None had taken part in any related studies. Nineteen participants were randomly assigned to each of the two conditions defined according to whether the same-font probes were to appear in the same case as the corresponding memory letter, or in the alternative case.

Materials. Four packs of cards were created in the same manner as for Experiment 1. However, a single font, Frankfurter Medium, was used throughout, and each pack comprised only 10 cards. The 10 letters selected for the experiment were chosen because they normally have dissimilar underlying structures in their uppercase and lowercase forms. The letters were: A, B, D, E, G, H, N, Q, R, and T. The five colours used were: red, blue, green, yellow, and pink. The recognition test cards were also created in the same way as for Experiment 1. All the test cards for the same-case condition incorporated probe letter shapes that were identical to the memory letter shapes. All the test cards for the different-case condition incorporated probe letter shapes that were in the case opposite to the one in which the memory letters had appeared.

Results

Table 2 gives the mean percentage correct colour recognition for the various conditions, scored without regard to whether the nature of the shape-colour association (unitary vs. separate) was also correctly recognized. ANOVA was undertaken on the number of correct responses, with probe type (same case vs. different case) as a between-participants factor, and unitariness (unitary vs. separate) as a within-participants factor. Neither the main effect of probe type, nor the main effect of unitariness, was significant: $F(1, 36) = 1.46$, $MSE = 1.52$, $p = .23$, and $F(1, 36) = 2.32$, $MSE = 0.96$, $p = .14$, respectively. The overall interaction between these two factors was significant, $F(1, 36) = 4.95$, $MSE = 0.96$, $p = .03$. Planned analysis of simple effects showed that although there was a unitization effect for same-case probes, $F(1, 36) = 7.02$, $MSE = 0.96$, $p = .01$,

TABLE 2
Experiment 2: Percentage correct recognition of colour associated with same-case probes and different-case probes for same-font letter shapes memorized under conditions of articulatory suppression

| | <i>Unitary</i> | <i>Separate</i> |
|-----------------------|----------------|-----------------|
| Same-case probes | 73.7 | 56.8 |
| Different-case probes | 56.8 | 60.0 |

there was no such effect for different-case probes, $F(1, 36) = 0.25$, $MSE = 0.96$, $p = .62$. For same-case probes, recognition was above chance only for the unitary displays: $t(18) = 5.15$, $SD = 1.00$, $p < .0001$, and $t(18) = 1.11$, $SD = 1.34$, $p > .10$, for unitary and separate displays, respectively. For different-case probes, recognition was not above chance for unitary displays, though it was above chance for separate displays: $t(18) = 1.18$, $SD = 1.26$, $p > .10$, and $t(18) = 2.92$, $SD = 0.75$, $p < .01$, for unitary and separate displays, respectively.

Discussion

The unitization effect was eliminated when memory for shape-colour associations was probed with different-case/same-font versions of the memory letters. Indeed, recognition performance fell to levels at, or close to, chance. It appears, therefore, that the unitization effect observed in Experiment 1 with same-case/different-font probes, did not arise because participants associated colour with representations of either the names of the letters, or their abstract identities. The irrelevance of letter names is consistent with another aspect of the results from Experiment 1, and with the more extensive observations reported by Walker and Cuthbert (1998). Thus, only when verbal recoding of the memory letters is precluded is a unitization effect observed. The evidence from several directions is remarkably consistent, therefore, in indicating that the unitization effect for shape-colour associations reflects the involvement of visual representations.

Supplementary observations

Although it was intended that the display fonts chosen for Experiment 1 would allow the same-case/different-font versions of each letter to be as visually dissimilar as the different-case/same-font versions used in Experiment 2, there was no formal check to determine if this had been achieved. It is possible, therefore, that different results emerged from the two experiments because the different-case/same-font letter pairs used in Experiment 2 were visually less similar to each other than were the same-case/different-font letter pairs used in Experiment 1. If so, and with regard to letters of the alphabet whose shape is contingent on case (e.g., *Aa*), then it would remain uncertain if the shape variation arising from changing font (which does not change the structural description) is qualitatively different from the variation arising from changing case (which yields a different structural description). Instead, the strength of the unitization effect might simply reflect the degree to which a probe letter is visually different from the corresponding memory letter.

The results from Experiment 1 indicate that the visual similarity of the memory and probe letters did not impact on the unitization effect (cf. Table 1). More specifically, despite choosing display fonts for which same-case/different-font letters would be visually dissimilar, recognition performance in the unitary condition was uninfluenced by the font in which the probe appeared. It seems,

therefore, that changing the visual appearance of a letter when it reappears as a probe need not, in itself, impact on shape–colour recognition memory. Nevertheless, supplementary observations were made to assess the extent to which the contrast between the two types of change imposed on the probe (i.e., font vs. case change) was confounded with differences in the degree of visual similarity of the memory and probe letters.

Black-on-white paper copies were prepared of all the nonidentical memory-probe letter pairs used in the two experiments (i.e., 23 same-case/different-font pairs from Experiment 1, and 10 different-case/same-font pairs from Experiment 2). The letters in each pair appeared side-by-side, and were reproduced to approximately the same size as in the experiments. Twelve students and administrative staff in the Psychology department at Lancaster University, who had not taken part in any related study, were asked to regard each letter as a 2D shape, and to judge how visually similar were the members of each pair. In an attempt to reduce the impact of the status of the shapes as letters, the sheet on which each letter pair was printed was rotated clockwise through 90°. When arriving at a judgement, participants were asked to take every aspect of the shapes into account. An 8-point rating scale was provided for them to express their judgements of visual similarity (1 = identical, 2 = extremely similar, 3 = very similar, 4 = quite similar, 5 = quite dissimilar, 6 = very dissimilar, 7 = extremely dissimilar, 8 = completely different). It was explained that they were not expected to use either end-point of the scale. They were not expected to use the first point because identical letter shapes would never appear as a pair. It was also suggested that they should assume that all the paired shapes have something in common regarding their visual appearance. The letter pairs were presented for rating in a different random order for each participant.

Friedman's ANOVA confirmed a significant level of agreement among participants, $\chi^2(32, N = 138) = 206, p < .001$, and the value obtained for Kendall's coefficient of concordance (W) was 0.54. The average similarity rating for the same-case/different-font letter pairs was 5.24 ($SD = 1.11$), and the average for the different-case/same-font letter pairs was 4.85 ($SD = 0.58$). If anything, therefore, the different-case/same-font letter pairs were visually more similar than the same-case/different-font pairs. However, both a participant-based analysis, and an item-based analysis, failed to reveal a significant difference between the two means, $t(11) = 1.32, p = .21$, and $t(31) = 1.04, p = .31$, respectively. To illustrate the feasibility of dissociating the type of change from the level of visual similarity, Figure 1 shows the two most dissimilar same-case/different-font letter pairs, and the two most similar different-case/same-font letter pairs. The letters in each of the two same-case/different-font pairings were significantly less similar visually than were the letters in each of the two different-case/same-font letter pairs, $F(1, 11) = 16.50, MSE = 0.73, p = .002$.

These supplementary observations confirm that the different effects arising from changing the font or the case of a probe letter are not a result of differences

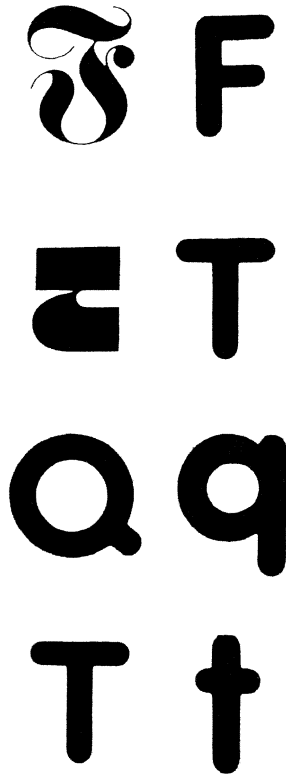


Figure 1. The two most visually dissimilar same-case/different-font letter pairs, and the two most visually similar different-case/same-font letter pairs. From top to bottom, the average rating for each pair was 6.67, 6.50, 4.20, and 3.75. Thus, whereas the top two pairs were judged to be somewhere between very dissimilar and extremely dissimilar, the bottom two pairs were both judged to be close to quite similar.

in the degree to which the probe is visually similar to the corresponding memory letter. Instead, the different effects appear to reflect a qualitative (categorical) difference in the nature of the change. This is consistent with the hypothesis that the visual representations of letter shape that are being linked to colour are structural descriptions, and that whereas case changes can give rise to different structural descriptions, font changes alone normally do not. Finally, the supplementary observations also confirm that, by selecting same-case/different-font probes in Experiment 1, the visual appearance of the letters was changed substantially. The fact that recognition memory for the shape-colour conjunctions was not perturbed by these changes, is further evidence that the visual similarity of the memory-probe letter pairs did not impact on performance.

GENERAL DISCUSSION

The present study demonstrates that visual memory for shape–colour conjunctions utilizes structural descriptions of shape. With letters as to-be-remembered forms, and specifically letters of the alphabet that differ in shape according to their case, these structural descriptions reveal themselves as case-specific, but font-independent representations.

That the representations of shape are not pictorial is indicated by the fact that recognition memory for shape–colour associations was not perturbed by quite marked changes in the visual appearance of the letters when they reappeared as recognition probes in a different font. That the representations are visual, and are not based on letter names, or the abstract identities of the letters, is indicated by the fact that recognition was at, or close to chance when a probe letter reappeared in the opposite case. The noninvolvement of verbal codes was also confirmed by the fact that a unitization effect emerged only when relevant articulation was suppressed during encoding of the memory letters (see Walker & Cuthbert, 1998, for more extensive evidence concerning the role of verbal recoding).

A claim for the existence of structural descriptions of letters should not be construed as a denial that other forms of letter representation exist also. For example, there is an emerging body of evidence, from both normal and clinical populations, for the abstract representation of letter identities (ALIs) (e.g., Adams, 1979; Baron & Strawson, 1976; Besner, Coltheart, & Davelaar, 1984; Bigsby, 1988; Coltheart, 1981; Coltheart & Freeman, 1974; Evett & Humphreys, 1981; Miozzo & Caramazza, 1998; Mozer, 1989; Rayner, McConkie, & Zola, 1980; Rynard & Besner, 1987; see Rapp et al., 2001, for a brief review). Rapp et al. (2001) claim that ALIs have a critical role in word reading, providing the interface code between current input and stored lexical orthographic knowledge. Clearly, however, the existence of ALIs does not preclude the existence of other forms of letter representation, including structural descriptions. For example, Miozzo and Caramazza (1998) document the case of a patient (GV) who seemed unable to derive ALIs from print. This deficit was most apparent when she was asked to say whether alternative case versions of a letter represented the same letter of the alphabet, or when she was asked to write the alternative case version of a presented letter. These difficulties stood in contrast to her ability to distinguish real from unreal letter shapes, and to state whether a letter rotated in the picture plane had been mirror reversed. Miozzo and Caramazza argue that access to ALIs is normally contingent on the prior derivation of structural descriptions of the letters, which they illustrate as being case-specific representations. They conclude from their observations of GV, that whereas she was able to derive structural descriptions for letters, she was unable to derive ALIs from these. Both in principle and in practice, therefore, structural descriptions and ALIs are not mutually exclusive forms of representation. Not only do the present results confirm the existence of the structural descriptions

referred to by Miozzo and Caramazza, they also indicate that, at least in the context of recognition memory for shape-colour conjunctions, colour can be linked to these descriptions.

Although Rapp et al. (2001) emphasize the important role of ALIs in providing access to the orthographic lexicon, it is clear that under some circumstances other forms of representation can play an important role in word reading. For example, there are many occasions where a reader of English needs to take letter case into account, such as when encountering familiar acronyms (e.g., BBC, NATO, and WHO). This would also be necessary when reading sentences such as: *I went to see Thomas Cook/cook, Noel is a typical Coward/coward, and I fell into the Farmers Arms/farmers arms*. Indeed, word recognition often demonstrates a sensitivity to the font as well as the case in which a word appears, as with most familiar brand names and many company logos. It appears, therefore, that the existence of ALIs does not preclude the involvement of other forms of representation in word reading.

Although letters normally appear as 2D shapes they can, and do in some fonts (e.g., the display fonts BlockDog and Block Up), appear as 3D objects. It is tempting, therefore, to speculate that the visual representations of shape revealed in the present experiments are equivalent to the structural descriptions proposed for "real" 3D objects. For example, according to Biederman's Geon Structural Description (GSD) theory of object recognition (Biederman, 1987), objects are described mentally in terms of the shapes of their constituent parts (i.e., primitive volumetric forms or geons) and the spatial relationships between these parts. Parts and the spatial relations between them appear to be coded categorically (see Biederman, 1987, and, more recently, Rosielle & Cooper, 2001), allowing object recognition to tolerate variations in viewing conditions and object shape. As for letters in a particular case, therefore, the structural description that defines a category of object, such as a chair, can tolerate variation in the metric properties of the object's parts and their spatial organization, variation that occurs naturally across different exemplars from an object category. Thus, the legs of a chair need not be precisely perpendicular to the seat, can vary in length and thickness, and can be straight or curved. Indeed, they can be circular or square in cross-section, implying that structural descriptions of object categories must sometimes tolerate variation in the nature of the constituent parts. These are also the kinds of variations that can be encountered when individual letters, in a particular case, appear in a variety of fonts. If one accepts that object categories are mentally represented as structural descriptions, then for everyday objects and letters alike, visual representations can capture the category-defining structure of an item in a way that is tolerant to the visuospatial variations allowed by the category. A clear prediction from the present results is that if a unitization effect is observed for the shape-colour associations pertaining to 3D objects, then it will be a structural description of the object that is linked to colour, rather than a metrically specific representation.

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