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Word attributes and lateralization revisited: Implications for dual coding and discrete versus continuous processing

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Three attributes of words are their imageability, concreteness, and familiarity. From a literature review and several experiments, I previously concluded (Boles, 1983a) that only familiarity affects the overall near-threshold recognition of words, and that none of the attributes affects right-visual-field superiority for word recognition. Here these conclusions are modified by two experiments demonstrating a critical mediating influence of intentional versus incidental memory instructions. In Experiment 1, subjects were instructed to remember the words they were shown, for subsequent recall. The results showed effects of both imageability and familiarity on overall recognition, as well as an effect of imageability on lateralization. In Experiment 2, word-memory instructions were deleted and the results essentially reinstated the findings of Boles (1983a). It is concluded that right-hemisphere imagery processes can participate in word recognition under intentional memory instructions. Within the dual coding theory (Paivio, 1971), the results argue that both discrete and continuous processing modes are available, that the modes can be used strategically, and that continuous processing can occur prior to response stages.

In a literature review and five experiments I conducted several years ago (Boles, 1983a), it was concluded that the word attributes of imageability and concreteness have no clear effect on overall word recognition or on field asymmetries (lateralization) in word recognition. A third word attribute, familiarity/frequency, was found to be related to overall recognition but not to asymmetry.

It may be useful to briefly describe some of the literature and experimental findings leading to those conclusions, with reference to representative studies. Further citations may be found in Boles (1983a). First, with regard to the rated imageability of words, null effects on overall visual or auditory recognition were reported by three studies (e.g., Paivio & O'Neill, 1970), and on asymmetry by five studies (e.g., Schmuller & Goodman, 1979). Significant effects, by contrast, were found in three and two studies, respectively (e.g., Day, 1979).

Similarly, rated concreteness presented a mixed picture. Null or even negative effects (favoring low-concreteness words) were found in seven studies of overall recognition (e.g., Richardson, 1976) and in eight studies of asymmetry (e.g., Bradshaw, Nettleton, & Taylor, 1981), while significant positive effects (favoring high-concreteness words) were reported in another seven and six studies, respectively (e.g., Borkowski, Spreen, & Stutz, 1965; Hines, 1976).

Taking imageability and concreteness alone, therefore, it appeared that any effects of the attributes on overall or lateralized word recognition were questionable, since over half of the studies had failed to find effects. The conclusion was reinforced by the five original experiments I reported. Across the experiments, the mean correlation (r) of imageability to overall recognition was only +.12; that of concreteness to overall recognition was −.03. Both correlations were nonsignificant, and null results were also reported for the effects of imageability and concreteness on visual field differences in word recognition.

Turning to familiarity/frequency, the literature review was more positive in one respect: this attribute almost universally has been reported to affect overall recognition. Thus, twelve studies finding significant effects were cited (e.g., Howes & Solomon, 1951), with one exception showing a trend in the same direction (Orenstein & Meighan, 1976). Likewise, the five original experiments I reported found rated familiarity to correlate +.33 ($p < .001$) with overall recognition. Familiarity, however, did not affect field differences.

Although the results of the literature review and the experiments seemed congruent, an attempt was made to determine whether methodological variations might account for the sometimes positive results in the literature. Only one such variation could be identified: the studies reporting a significant interaction of a word attribute with field of presentation were those with small sample sizes. This finding, of course, reinforced the conclusion that such interactions are not veridical.

The full set of conclusions was viewed as important because of its bearing on one of the few theories to state explicit connections between verbal and imaginal memory codes, Paivio's (1971) dual code theory. According to the theory, the *representational* meaning of a word is indexed

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by its familiarity/frequency, while its *referential* meaning is indexed by imageability, concreteness, and rated meaningfulness. The theory states that for a word to be recognized, it must access its representation in memory (verbal code). Only following recognition can it access its associated referential meanings. Therefore, only familiarity/frequency should affect near-threshold word recognition, not the attributes of imageability and concreteness. The argument applies equally to overall recognition and to field effects. Accordingly, the results of the literature review and original experiments were seen as highly congruent with the dual code theory.

Furthermore, the conclusions were seen as having implications for discrete versus continuous processing (Eriksen & Schultz, 1979; McClelland, 1979). It is clear, from the description given above, that Paivio's theory is basically a discrete one, in which one stage of processing must be completed before another begins. The conclusion that referential memory (imagery) does not affect near-threshold word recognition was viewed as supportive of the discrete nature of the theory (i.e., words apparently must be recognized before contact can be made with associated imagery).

Since the time of the review, a number of further studies have been published. In general, these have tended to support a main effect of imageability on word recognition (Lambert & Beaumont, 1983; Leiber, 1982; Rodel, Dudley, & Bourdeau, 1983), but have continued to present a mixed picture of imageability effects on asymmetry (on the null side, Lambert & Beaumont, 1983, and Leiber, 1982; on the positive side, Rodel et al., 1983; and Young & Ellis, 1985). Concreteness has sometimes failed to produce a main effect (Lambert & Beaumont, 1983), but others have reported more positive effects (Kroll & Merves, 1986; Prior, Cumming, & Hendy, 1984). Concreteness has not, however, produced recent interactions with asymmetry (Lambert & Beaumont, 1983; Prior et al., 1984). Finally, as might be expected, familiarity consistently has continued to exert a main effect (Balota & Chumbley, 1984; Frost, Katz, & Bentin, 1987; Leiber, 1982; Segui, Mehler, Frauenfelder, & Morton, 1982; Young & Ellis, 1985).

Thus, the results of recent research do not appear to require much change in the previous conclusions. Although there are somewhat more positive indications of a main effect of imageability on word recognition, the literature on the main effect of concreteness continues to be mixed, and neither word attribute interacts consistently with asymmetry. Taking the old and new literature together, it seems reasonable to conclude that only familiarity/frequency affects word recognition, while imageability and concreteness do not do so, or at least not with any consistency.

Recently, however, a serendipitous finding posed a potential challenge to these conclusions. As a laboratory exercise in an undergraduate classroom, I presented high- and low-imageability words to students in a visual field paradigm. It was expected that several established phenomena would be demonstrated: (1) a right visual field (RVF) advantage for word recognition, (2) the failure of the RVF advantage to interact with imageability, and (3) the lack of an imageability main effect. The laboratory exercise differed in one major respect from my experiments, however. Wishing to pack the maximum learning experience into a small package, I tested the students on memory for the words following their participation, having informed them at the outset that they should remember the words. The intent, of course, was to replicate the well-established finding that imageability affects word memory (for recent examples see Beatty & Butters, 1986; and Matthews, 1983; for a review see Paivio, 1971).

Although collected on a small sample with few trials and under less than ideal conditions, the results were striking. The expected RVF advantage was found (42% correct RVF, 34% LVF), but a main effect of imageability was also found (42% and 34% correct for high- and low-imageability words, respectively). There was even a hint of a visual field by imageability interaction, with a RVF advantage of +9% for low-imageability words, and +6% for high-imageability words. In recall, the expected imageability effect appeared strongly (39% and 27% correct recalls for high- and low-imageability words, respectively).

It seemed possible that, quite by accident, an important methodological variable had been identified—incidental versus intentional memory for the words used in the stimulus set. Intentional memory instructions appeared to have produced a main effect of imageability on word recognition, and possibly an interaction with visual field. Experiment 1 was the attempt to replicate the findings under more controlled conditions.

EXPERIMENT 1

Method

Subjects. Seventeen subjects participated for less than 1 h each. There were 9 males and 8 females, and all subjects self-reportedly were right-handed.

Apparatus and Stimuli. Stimuli were presented using an Apple IIe microcomputer and a Monitor III, with a P4 phosphor. Stimulus presentations were synchronized with the monitor's raster scan. Typed word responses were collected on the computer keyboard. A limitation of the supporting software was that no more than 15 letters could be "active" at any one time on the keyboard. This limitation was surmounted through programming so that, depending on which five-letter word stimulus had been selected on a particular trial, those letters were activated, and another set of letters was selected at random, for a total of 15. A chinrest was used to enforce a viewing distance of 0.48 m.

To provide continuity with previous work, it was considered desirable to select one of the stimulus sets used earlier (Boles, 1983a). The stimulus set from Experiment 1 of the earlier report was selected because it had produced results that were highly representative of the full set of experiments. The stimuli were in four sets of eight words each, comprising (1) low-imageability, low-concreteness words (CRAFT, CRUSH, FLIRT, HORDE, INDEX, PIVOT, TOKEN, VIRUS), (2) high-imageability, low-concreteness words (FAIRY, FIGHT, FLASH, GNOME, GROUP, LIGHT, WATCH, WITCH), (3) low-imageability, high-concreteness words (BLOCK, BRINE, CHIMP, DIVOT, GRANT, MIDGE, OPIUM, WIDTH), and (4) high-imageability, high-concreteness words (CLOWN, DRUNK, HOUND, LUNCH, RANCH, SCOUT, UNCLE, YOUTH). Means and standard deviations for imageability and concreteness, calculated for each set using the ratings of Gilhooly and Hay (1977), were reported in an earlier study (Boles, 1983a).

Bilateral presentations of stimuli have been shown to enlarge visual field asymmetry (Boles, 1983b, 1987). Accordingly, bilateral displays were used in Experiment 1. On each trial, a stimulus word was randomly selected and paired with a distractor word that also was randomly selected from the stimulus set. The stimulus was shown in one visual field, with the distractor in the opposite field, both in a vertical orientation. A central arrowhead (< or >) was shown simultaneously to indicate the word to be recognized. Words subtended 0.5° by 3.7° horizontally and vertically, and were at 2.9° eccentricity, as measured to their near edges. The central arrowhead measured 0.3° by 0.6°. The stimulus display was followed by a mask comprised of columns of Xs, which appeared in the same locations as the words.

Procedure. A trial began with the presentation of a small square at central fixation, shown for 750 msec. The subjects were instructed to fixate in the center of the square. After its disappearance, there was a blank period of 100 msec, followed by a stimulus display for 67 msec, another 100-msec blank, and the mask for 67 msec. A string of five question marks appeared next, centered toward the bottom of the screen. As the subject typed in the response, each question mark was replaced by a typed letter. After all five letters were displayed, they were removed, and the message PRESS "I" FOR NEXT TRIAL appeared. When the subject pressed the I key, a blank period of 500 msec ensued before the next trial began. No feedback was given.

The subjects were informed that not all letters were active on the keyboard at any one time and that backspaces were not allowed during the response. They were also told to be as accurate as possible but to guess if necessary, and if an error was made, to "just finish typing in letters and go on to the next trial." Most importantly, the subjects were told that at the end of the experiment they would be asked to recall as many of the words as possible, and therefore it was important to remember the words they recognized and typed in.

Trials were organized in blocks of 64, with visual field, word set, and stimulus within a word set mixed randomly within each block. Two blocks were given, with no practice, so that each stimulus was presented twice per visual field. At the completion of Experiment 1, each subject was given a sheet of paper and asked to write down the words he/she had recognized.

Results

Accuracy was assessed separately for the recognition of the words (typed responses) and for the recall of the words at the completion of the experiment.

Recognition. Following previously established procedure (Boles, 1983a; Boles, Rogers, & Wymer, 1982), the data were first checked for correlations between accuracy (overall percent correct) and asymmetry (RVF−LVF, in percent correct). It was found that in two of the four word sets, the correlation across subjects was significant ($r = +.70$ and $+.73$, both $p < .01$). Accordingly, laterality coefficients (LCs) were calculated in lieu of visual field difference scores (Bryden, 1982; Marshall, Caplan, & Holmes, 1975). The LC score corrects for floor or ceiling effects by dividing the difference between (1) percent correct (RVF−LVF) by the summed percents correct (RVF+LVF), if accuracy is less than 50%, or (2) percent error (LVF−RVF) by the summed percents error (LVF+RVF), if accuracy is greater than 50%. For example, the analogous results 70% correct RVF − 60% correct LVF, and 40% correct RVF − 30% correct LVF, both generate LC scores of +.14. When calculated, it was found that LC was uncorrelated to overall accuracy in all four word sets (all $ps > .3$). Thus, as a means of comparing word sets that might differ in overall accuracy, it was considered better than the visual field difference score.

LC scores were subjected to a two-factor analysis of variance (ANOVA), using the factors of imageability (low vs. high) and concreteness (low vs. high). The only significant effect was that of imageability [$F(1,16) = 5.33$, $MSe = .19$, $p < .05$]. As shown in Table 1, low-imageability words produced a larger LC than did high-imageability words (+.34 vs. +.10). For illustrative purposes, this effect can also be described in terms of percent correct: low-imageability words produced a larger RVF advantage (RVF 23.7%, LVF 11.0%, difference = +12.7%) than did high-imageability words (RVF 34.0%, LVF 25.9%, difference = +8.1%). The overall LC of +.22 also was significant [$t(16) = 2.79$, $SD = .33$, $p < .02$], corresponding to a main effect favoring the RVF.

Although calculating LC scores was necessary for the visual field analysis, such scores obscure the effects of imageability and concreteness on overall accuracy since they are expressions of asymmetry only. Accordingly, an ANOVA with the factors of imageability and concreteness (collapsing over visual field) was conducted on percent correct scores. The only significant effect was that of imageability [$F(1,16) = 30.72$, $MSe = 4.49$, $p < .001$]. High-imageability words were recognized better than low-imageability words (30.0% vs. 17.4%).

Following the procedures of Boles (1983a), analyses were also carried out across stimuli rather than across subjects. Such analyses were necessary to examine the effects of rated familiarity on overall word recognition and on asymmetry, since familiarity was not varied orthogonally with respect to the other word attributes. With respect to overall recognition, rated familiarity (Gilhooly & Hay, 1977) correlated highly to percent correct across stimuli, with the effects of imageability and concreteness partialled out ($r = +.74$, $p < .001$). Imageability correlated moderately to percent correct with familiarity and concreteness partialled out ($r = +.32$, $p = .08$), as did

Table 1
Laterality Coefficients for Low- and High-Imageability Words in Experiments 1 and 2

Experiment	Imageability: Low	Imageability: High
1	+.34	+.10
2	+.31	+.29

concreteness with familiarity and imageability partialled out ($r = +.34$, $p = .06$).

With respect to asymmetry, familiarity did not correlate significantly to LC scores calculated for each stimulus ($r = -.15$), nor did concreteness ($r = -.04$). Imageability, however, did show a significant relationship ($r = -.36$, $p < .05$). The negative correlation indicates that higher imageability values were associated with lower LC values, and vice versa, so that the results of the stimuluswise analysis concur with those of the subjectwise analysis.

Recall. For each subject and each condition, the number of words correctly recalled at the end of Experiment 1 was tallied and converted to percent correct, then subjected to an ANOVA with imageability and concreteness as factors. The analysis showed only a main effect of imageability [$F(1,16) = 18.20$, $MSe = 1.56$, $p < .001$]. More of the high-imageability words were recalled than low-imageability words (26.1% vs. 9.9%).

A stimuluswise analysis was also conducted. Imageability was found to correlate to the number of subjects who recalled a word, with concreteness and familiarity partialled out ($r = +.36$, $p < .05$). Concreteness did not show a significant partial correlation ($r = +.06$), but familiarity did do so ($r = +.50$, $p < .01$).

Discussion

The results of Experiment 1 give strong confirmation to the observations made in the classroom situation. When intentional memory instructions were given, imageability influenced both visual field asymmetry and overall word recognition. Furthermore, they did so in the directions reported by previous research that found such effects. Thus, high imageability was associated with increased overall recognition and with a reduced RVF advantage. In fact, the reduced RVF advantage, an LC value of +.10, was not itself significant [$t(16) = 1.03$]. It is noteworthy that the effect of imageability on asymmetry was significant in both the subjectwise analysis and the stimuluswise analysis, with the effects of the other word attributes partialled out.

Familiarity correlated strongly with overall recognition, but not with asymmetry. Concreteness played a more ambiguous role, showing no relationship to overall recognition in the subjectwise analysis ($F < 1$), but a marginally significant relation in the stimuluswise analysis. However, it is clear that concreteness showed no relationship to asymmetry.

It is instructive to compare these results with those obtained earlier using the identical stimulus set, but slightly varying methodology (Boles, 1983a). Imageability produced no effect on asymmetry in the earlier results ($p > .7$), as opposed to the significant effect here ($p < .05$). It did not correlate with the earlier overall recognition, with the other attributes partialled out ($r = +.04$), but did so here ($r = +.32$, $p = .08$; also $p < .001$, in the subjectwise analysis). With respect to familiarity, both studies showed an effect on overall recognition ($r = +.49$, $p < .01$; and $r = +.74$, $p < .001$). Concreteness did not show a relationship to overall recognition in the earlier results ($r = +.10$), but, as noted above, it showed an ambiguous relationship in the present results. Concreteness was not related to asymmetry in either study (both $ps > .2$).

The overall picture, therefore, is one of change in the imageability results. The contrast suggests that the incidental versus intentional memory dimension is critical, because subjects were not told to remember the words in the earlier experiment. Before this conclusion could be drawn with confidence, however, it was desirable to determine whether the earlier results could be reinstated by reproducing Experiment 1 with the memory instructions deleted. Experiment 2 was the replication of those results.

EXPERIMENT 2

Method

A new sample of 16 subjects was employed for Experiment 2. Ten were males and 6 were females, and all self-reportedly were right-handed.

The apparatus, stimuli, and procedure were identical to those of Experiment 1, with one exception: the subjects were not asked to remember the words for later recall.

Results

Recognition. As before, an initial check was made on the correlation between asymmetry (RVF−LVF, in percent correct) and overall accuracy, in each condition. A significant correlation was found in one of the four word sets ($r = +.60$, $p < .02$). For that reason, and also to maintain consistency across experiments, visual field differences were expressed as LC scores. In none of the four conditions were LC scores significantly correlated to overall accuracy (all $ps > .5$).

The two-factor ANOVA on LC scores produced no significant effects (all $Fs < 1$). As shown in Table 1, the mean LC for low-imageability words was +.31, while that for high-imageability words was the nearly identical value of +.29. In terms of percent correct, low-imageability words produced virtually the same field difference (RVF 20.5%, LVF 10.6%, difference = +9.9%) as did high-imageability words (RVF 31.6%, LVF 21.3%, difference = +10.3%). The grand mean LC of +.30 was significant, supporting a generalized RVF advantage [$t(15) = 3.26$, $MSe = .37$, $p < .01$].

The ANOVA conducted for the purpose of assessing imageability and concreteness effects on overall recognition showed all three effects to be significant or marginally significant. There were main effects of imageability [$F(1,15) = 22.27$, $MSe = 4.40$, $p < .001$], and marginally of concreteness [$F(1,15) = 3.63$, $MSe = 2.79$, $p = .07$]. Their interaction was also significant [$F(1,15) = 5.48$, $MSe = 2.52$, $p < .05$]. The interaction can be viewed as a greater effect of imageability for high-concreteness words (26.8% vs. 11.7% for high- vs. low-imageability words, difference = +15.1%) than for low-concreteness words (26.2% vs. 19.4%, difference = +6.8%).

Much different results were produced by the stimuluswise analysis, however. With the effects of the other two word attributes partialled out, there was a significant correlation to overall recognition only of familiarity ($r = +.71$, $p < .001$), not of imageability ($r = +.14$) or concreteness ($r = +.10$). None of the word attributes correlated to LC scores calculated for each stimulus (all $ps > .10$).

Recall. The two-way ANOVA showed only a main effect of imageability [$F(1,15) = 14.99$, $MSe = .82$, $p = .001$]. High-imageability words produced better recall than low-imageability words (19.1% vs. 8.3%).

The stimuluswise analysis showed no significant or marginally significant relationship of imageability or concreteness to recall, with the other word attributes partialled out ($r = +.22$ and $+.01$, respectively). Familiarity, however, showed a significant partial correlation ($r = +.50$, $p < .01$).

Discussion

With respect to asymmetry, the results of Experiment 2 are clear. Transforming the memory portion of the task into one of incidental, rather than intentional, memory eliminated the effect of imageability on the RVF advantage. Indeed, the bulk of the difference in results was due to the high-imageability words, with mean LC shifting between experiments from +.10 to +.29. Low-imageability words produced near-constant LCs of +.34 and +.31. The result is precisely what would be expected if the right hemisphere could participate in the recognition of imageable words, and if this capacity was evoked in Experiment 1 but not in Experiment 2.

Evidence on the relationships between imageability, concreteness, and overall recognition appears to be conflicting in Experiment 2. The ANOVA indicates that both main effects and the interaction were at least marginally significant, while the stimuluswise partial-correlation analysis shows no effect of either word attribute. In considering this apparent conflict, it should be kept in mind that when the four word sets were originally constructed, no attempt was made to equate them on rated familiarity (Boles, 1983a). The rationale at the time was that since familiarity shows only modest correlations with imageability and concreteness, a partial-correlation approach would be sufficient to separate the effects of the word attributes, as long as the otherwise highly related dimensions of imageability and concreteness were orthogonally varied.

It can be demonstrated with reasonable certainty that the ANOVA results are due to the uncontrolled variable of familiarity. First, as noted above, when familiarity and the remaining word attribute are partialled out, the correlation between overall recognition and imageability falls to nearly zero ($r = +.14$), as does that between overall recognition and concreteness ($r = +.10$). This is in spite of the fact that a stimuluswise analysis shows the *raw* correlation between overall recognition and concreteness to be significant ($r = +.38$, $p < .05$). In other words, the raw correlation confirms the effect of imageability that appeared in the ANOVA, but the effect disappears when familiarity is accounted for. Thus, it seems certain that the ANOVA main effects were due to the confounding influence of familiarity.

Furthermore, the interaction present in the ANOVA almost exactly mirrors variations in mean familiarity over the four word sets. The low imageability-low concreteness, high imageability-low concreteness, low imageability-high concreteness, and high imageability-high concreteness sets showed mean recognition levels of 19.4%, 26.2%, 11.7%, and 26.8%, respectively. Mean familiarity ratings on a seven-point scale (standard deviations in parentheses) were 3.84 (.68), 4.69 (1.45), 3.53 (1.17), and 4.44 (1.31), respectively. The correlation between the two sets of means is $r = +.95$. Therefore, the interaction and the main effects from the ANOVA appear to be due to a confound with familiarity.

Accordingly, the partial-correlation analysis can be taken as representative in this instance. Familiarity was demonstrated to influence overall recognition in Experiment 2, but not imageability or concreteness.

Finally, the recall results from Experiment 2 reproduced the effect of imageability, with high-imageability words producing greater recall than low-imageability words, at least in the subjectwise analysis. The stimuluswise analysis did not show a significant effect of imageability, but the trend was in the same direction ($r = +.22$).

GENERAL DISCUSSION

In summary, rated imageability has been identified as an important influence on the overall level and visual field asymmetry of word recognition. It appears to have such influence, however, only when subjects attempt to memorize the words that they recognize. The variable of intentional versus incidental memory thus appears to be a critical one in research of this kind.

It is important to recognize, however, that these conclusions rest on a comparison of results between different experiments using different subjects. Ideally, one would like to manipulate the intentional versus incidental variable within the same subjects to provide a powerful statistical comparison between outcomes. Nevertheless, such a design purposely was not used because it was not clear that a within-subject manipulation would be appropriate. Specifically, it seemed likely that proactive interference over the two conditions would at minimum contaminate the recall results, and might interact in unpredictable ways with the influence of imageability and concreteness on both recognition and recall. In addition, it did not seem reasonable to expect that subjects would abandon a successful (intentional) memory strategy for a less successful one (incidental), for the subjects receiving the intentional condition first. For these reasons, a between-subjects design was used. One can still combine the two experiments into overall analyses, but the problem with a between-subjects design is that it has low power.

Nevertheless, an attempt has been made to conduct a relatively powerful comparison of the LCs between the two experiments. In the analysis, the subjects from the experiments were assigned to matched pairs on the basis of their LC scores for the low-imageability words. Assignment was unbiased in that the subject with the largest low-imageability LC in Experiment 1 was paired with the subject from Experiment 2 who was least discrepant in that regard, and so on down to the subject with the smallest low-imageability LC. Since there were 17 subjects in Experiment 1 and only 16 in Experiment 2, the one subject who would have produced the largest discrepancy with a matched partner was eliminated from Experiment 1. The resulting matched pairs were nearly identical in their mean LCs for the low-imageability condition: the means for the subjects in Experiments 1 and 2 were +.34 and +.31, respectively, and the correlation between pair members was $r = +.98$.

Having matched the pairs on their LCs for low-imageability words, the significance of the difference between LCs for high-imageability words can be assessed with a correlated-groups t test and a binomial test. The t test indicates a marginally significant difference between the LCs [$t(15) = 1.93$, $SD = .46$, $p = .08$]. Furthermore, 13 of the 16 pairs showed a larger LC for the subject from Experiment 2, an unambiguously significant result ($p = .02$).[1]

This outcome lends a reasonable degree of support to the interpretation that the experimental outcomes are truly different. In addition, recall that (1) five previous experiments using the same word stimuli failed to find an influence of imageability on asymmetry, under incidental memory conditions (Boles, 1983a), and that (2) the classroom demonstration mentioned in the introduction showed a trend toward the effect, under intentional memory conditions. Across the sources of evidence, it seems apparent that visual field asymmetry for high-imageability words is lower when intentional memory instructions are given than when incidental instructions are given.

The results carry considerable potential for resolving existing conflicts in the literature. A number of studies have reported effects of imageability on overall or lateralized word recognition (Day, 1979; Lambert & Beaumont, 1983; Leiber, 1982; Marcel & Patterson, 1978; Rodel et al., 1983; Schmuller & Goodman, 1979; Young & Ellis, 1985), while a number of others have not (Bradshaw et al., 1981; Haynes & Moore, 1981; Kelly & Orton, 1979, as interpreted by Lambert & Beaumont, 1982; Paivio & O'Neill, 1970; Richardson, 1976; Saffran, Bogyo, Schwartz, & Marin, 1980). Unfortunately, the instructions that were given to subjects have generally been poorly reported, so it is not possible to retrospectively determine whether the intentional-incidental dimension accounts for the conflicting findings. The dimension can nevertheless be used prospectively in future research.

Another important conclusion from the two experiments is that, across the board, effects of imageability were clearer than those of concreteness. One of the original aims in orthogonally varying the two attributes was to determine whether one showed preeminent effects (Boles, 1983a). In terms of the recognition results, only imageability was found to influence visual field differences (Experiment 1). It also influenced overall recognition, marginally or significantly, in both the ANOVA and the partial correlation analyses. The role of concreteness was ambiguous, since a main effect appeared only marginally through partial correlation. In terms of recall, the contrast between word attributes was even clearer, with only imageability determining the level of recall (Experiments 1 and 2).

In this regard there is little conflict with the previous literature. Most research that has examined the role of concreteness in word recognition has failed to orthogonally vary imageability. Therefore, when concreteness has reportedly exerted an effect (Borkowski et al., 1965; Day, 1977; Ellis & Shepherd, 1974; Elman, Takahashi, & Tohsaku, 1981; Hatta, 1977; Hines, 1976; Jones & Spreen, 1967; Kroll & Merves, 1986; McFarland, McFarland, Bain, & Ashton, 1978; Prior et al., 1984; Riegel & Riegel, 1961; Spreen, Borkowski, & Benton, 1967; Sugishita, 1978), it might well have done so because of the high correlation between concreteness and imageability (Paivio, Yuille, & Madigan, 1968). In two studies that orthogonally varied these attributes, Richardson (1976) found no effect of either one, while Marcel and Patterson (1978) reported that imageability, but not concreteness, influenced word recognition.

Identification of imageability as an important influence has implications for hemispheric asymmetry in word recognition and for Paivio's (1971) dual code theory. The reduction in the RVF advantage that is found for highly imageable words, under intentional memory instructions, implies that the right hemisphere can participate in the recognition of such words. Data from a split-brain subject have been interpreted as supporting the linguistic capability of the isolated right hemisphere, particularly for concrete (i.e., imageable) words (Sugishita, 1978). It remains an open question, of course, whether the right hemisphere of the normal brain actually recognizes such words or merely contributes toward recognition through the participation of imagery processes. This remains an issue for further investigation.

With regard to Paivio's model, recall that, according to the theory, word stimuli first must be recognized via their representational (verbal) memory code, and only then do they access their referential (associated imagery) code. The model is hierarchical (with processing levels) and discrete (with one stage of processing requiring completion before another commences). According to the model, therefore, imageability should not influence near-threshold word recognition, since its influence should operate only after recognition is complete. The existence of such influences would seem to require a revision in the model.

However, the dual code model would not require revision if the observed effects of imageability occur only on word recognitions that are *subsequent* to the first recognition. This is because the initial recognition of a word should allow access to associated imagery. Activated imagery, in turn, presumably could feed back to keep the representational (verbal) code activated for the word, which, in turn, should improve the chances for its subsequent recognition.

Attractive as this notion is as a means of reconciling Paivio's model and the observed effects of imageability, further analysis of the data from Experiment 1 suggests that it is false. In this analysis, only the first recognition of a particular word was scored. Subjectwise, the data, therefore, are counts of the number of high- and low-imageability words that were recognized at least once by each subject, with the counts convertible to percentages. Since increments in the counts are due solely to first recognitions, there should be no effect of imageability if the imageability effects occur only on later recognitions. However, in fact, more high-imageability words were recognized than low-imageability words [54.4% vs. 35.3%; $F(1,16) = 26.81$, $MSe = 1.48$, $p < .001$].[2] The result also receives a reasonable degree of support from a stimuluswise partial-correlation analysis, in which the data are counts of the number of subjects who recognized each word at least once. The correlation between imageability and the number of subjects was $r = +.30$ ($p = .10$), with concreteness and familiarity partialled out.

Because of the considerable theoretical significance of the finding that imageability affects the first recognition of words, and the marginal nature of the support afforded the effect by the stimuluswise analysis, a third comparison was undertaken to clarify it. In this analysis, the original set of 32 words was trimmed to two sets of 11 words each, differing on mean imageability (3.99 vs. 5.46), but closely matched on mean concreteness (5.10 vs. 5.16), and especially on mean familiarity (4.08 vs. 4.05). The trimming process was unbiased in that words were selected from the low-imageability words strictly in order of decreasing familiarity, while others were selected from the high-imageability words strictly in order of increasing familiarity, until the mean familiarity values of the new low- and high-imageability sets were matched. The intent was to perform a fair subjectwise comparison, using a stimulus set in which imageability was not confounded with familiarity. The result of the comparison was quite clear: more high-imageability words were recognized at least once (51.9%) than low-imageability words [42.8%; $t(16) = 2.38$, $SD = 15.7$, $p < .05$].

It seems, therefore, that imageability affects word recognition from the outset, not simply after recognition has occurred. Thus, the original dual code model appears inadequate to explain the imageability effects.

A Revised Dual Code Model

It will be argued here that the discrete nature of Paivio's dual code model has not been refuted, but rather constrained. Recall that Experiment 2 produced no convincing evidence for effects of imageability on visual field asymmetry or on overall recognition. Familiarity, on the other hand, had a large effect on the latter. Taken alone, those results are perfectly consistent with the tenets of Paivio's theory. That is, familiarity affects recognition because of its relationship to the representational (verbal) code, while imageability has no effect, because it indexes the referential (imagery) code. Under incidental learning instructions, in other words, the system appears discrete. Of course, once words are recognized they may then access associated imagery, affecting memory for the words and producing the observed effect of imageability on subsequent recall.

The results of Experiment 1 suggest that under intentional memory instructions, the system is no longer discrete. Apparently, the verbal and imagery codes are linked in a continuous, or "cascade," fashion (Eriksen & Schultz, 1979; McClelland, 1979). In a continuous system, imageability can influence recognition, since recognition need not be completed via the verbal code prior to activation of the imagery code. As the imagery code is activated, it then can feed back to further activate the verbal code, aiding the recognition of the words.

More generally, this framework leads to a view of the information processing system as bimodal: operating alternatively in either a discrete or continuous mode, depending on the perceived demands of the task. Undoubtedly, in many situations, we believe that one particular type of encoding is all that is necessary for the successful completion of a task. The system might then be "set" in a discrete mode to accomplish this limited encoding. In other situations, however, we may perceive a need to extract varied codes for the information we are processing. To take the present example, the attempt to recognize and memorize words is perceived to benefit from imagery associated with the words. Perceived task demands along these lines call for a continuous, rather than a discrete, processing mode, for which the system presumably may also be set.

If this view is correct, the present results appear to have contributed to our understanding of discrete versus continuous processing in three ways. First, they emphasize the existence of both modes, rather than the existence of one over the other. Second, they indicate the strategic manner in which the modes may be used, since instructional set appeared effective in switching subjects between one and the other in the present study. Third, they argue that processing can be continuous in stages prior to response processes, which until now have been the major focus for the discrete-continuous debate (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985).

In respects other than the discrete versus continuous nature of processing, the present results do not require revisions of the dual code model. In fact, they are consistent with Paivio's (1971) conjecture that imagery processes are predominantly lateralized to the right cerebral hemisphere. Evidence from other paradigms also lends support to the conjecture (Bersted, 1983; Hatta, 1983; Kerr & Foulkes, 1981), although an opposing view has also been expressed (Farah, 1986).[3]

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NOTES

1. An ANOVA with the factors of imageability, concreteness, and experiment produces a similar parametric result for the imageability by experiment interaction [$F(1,31) = 2.87$, $MSe = .15$, $p < .10$]. When gender is added as a variable, it fails to affect the interaction ($F < 1$), indicating that the slightly higher proportion of males in Experiment 2 is of little concern. In addition, overall accuracy levels in Experiments 1 and 2 were comparable (23.7% vs. 21.0%), and collapsing over experiments, a subject's LC for high-imageability words was not significantly correlated to the percent correct for those words ($r = -.02$). Thus, overall accuracy level also is of little concern.

2. An anonymous reviewer suggests that scoring the first presentation of a word, rather than the first recognition, would make the results less susceptible to subthreshold priming from prior "near misses." The suggestion misses the point, however, in that under Paivio's (1971) discrete model, such priming should not occur. If it does occur, it is an indication of continuous processing, in that subthreshold activation of imagery would presumably be responsible for the difference between high- and low-imageability words. Thus, the suggested confound is actually isomorphic with the effect that the first-recognition analysis intends to uncover.

3. An anonymous reviewer notes that the opposing view, which states that imagery is a predominately left hemisphere function, can account for the present results, under the assumption that evoked imagery interferes with the verbal processing of RVF words. Trends in the data, however, tend to argue against the view. Specifically, under intentional memory instructions, which are proposed to evoke imagery, RVF recognition of high-imageability words does not decrease relative to incidental instructions (34.0% vs. 31.6%, respectively).

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