Notes and Comment

Age of acquisition and visual field asymmetry in word recognition

DAVID B. BOLES, STEVEN ROGERS,
and WILLIAM WYMER
New College of the University of South Florida
Sarasota, Florida

Evidence that the normal adult hemispheres play differential roles in recognizing abstract and concrete words is accumulating. Thus, the left hemisphere has little difficulty identifying both abstract and concrete words, whereas the right hemisphere is equal to the left in recognizing concrete words, but inferior in recognizing abstract words (Day, 1977, 1979; Ellis & Shepherd, 1974; Elman, Takahashi, & Tohsaku, 1981; Hines, 1976; McFarland, McFarland, Bain, & Ashton, 1978; Sugishita, 1978). While several researchers have pursued an explanation of this dissociation based on imagery-mediated word recognition in the right hemisphere (e.g., Day, 1979; Seamon & Gazzaniga, 1973), Ellis and Young (1977; Young & Ellis, 1980) suggested a novel hypothesis, that a differential age of acquisition might account for the results. They proposed that early-learned words tend to be concrete relative to late-learned words and that, therefore, a modification of a developmental hypothesis proposed by Gazzaniga (1974) could account for their differential lateralization.

In its modified form, this hypothesis is as follows: (1) With myelination of the corpus callosum incomplete until the age of 2 years or after, the young child essentially functions as a "split brain," (2) prior to this age, the two hemispheres of the brain have little intercommunication, with one consequence being that words learned before the age of 2 years are learned by both hemispheres, and (3) after the age of 2 years, the left hemisphere exerts a kind of dominance for language, actively inhibiting the right hemisphere so that later learned words are acquired largely by the left hemisphere. Consequently, according to Ellis and Young (1977), the adult shows visual field asymmetry in recognizing the later learned abstract words, but no asymmetry for earlier learned concrete words.

The developmental hypothesis may be criticized on at least two grounds, that it relies too heavily on the ill-

supported assumption that the young child has a "split brain" and that it fails to consider possible changes in lateralization with age. However, neither criticism is fatally damaging to the theory, and so Ellis and Young (1977; Young & Ellis, 1980) attempted to test it.

Using words rated for age of acquisition, they found that in adults, early-acquisition words and late-acquisition words showed essentially identical asymmetry in recognition in favor of the right visual field (RVF) and right ear over the left visual field (LVF) and left ear. This outcome was interpreted as evidence against the developmental hypothesis, which predicts asymmetry only for late-acquisition words.

While this outcome would appear to lay to rest any notion that age of acquisition might account for differential recognition asymmetry of concrete and abstract words, the studies have two unfortunate flaws that cast doubt on their interpretation.

First, the word population had been rated for age of acquisition by adults, who might therefore have employed retrospective or stereotypical strategies in rating the words; that is, it is not clear that age of acquisition is a dimension suitable for rating techniques, particularly for very early-acquired words. Second, even assuming that ratings are suitable, the mean rated ages of acquisition for early-acquisition and late-acquisition words, respectively, were 4.5 and 8.5 years. Clearly, according to the developmental hypothesis, asymmetry should emerge for both word sets, since both are after the critical age (2 years). Since this was in fact the finding, the studies by Ellis and Young hardly constitute evidence against the hypothesis.

In our work, we have attempted to overcome these deficiencies by using a corpus of words actually observed in the speech of young children. The monograph by Nelson (1973) served as our source, drawing on the first 50 words acquired by each of 18 children. As stated by Nelson, this vocabulary size was reached at a mean age of just under 20 months.

METHOD

Stimuli

The words, selected from the corpus of Nelson (1973), fell into three categories: (1) Words used by at least 10 of the 18 children (mean = 12.4, SD = 2.1), defined as *early-acquisition* words, since more than a majority of the children had acquired them in their first 50 words. The words were: ball, car, cat, cookie, dog, juice, milk, and shoes. (2) Words used by 2 to 8 of the 18 children (mean = 6.0, SD = 2.1), defined as *middle-acquisition* words, since fewer children had acquired them, the assumption being that the other children would acquire them at a later age, resulting in a later mean age of acquisition. The words were: blocks, boat, cup, duck, key, pea, toast, and water. (3) Words used by none of the 18 children (mean = 0, SD = 0), defined as *late-acquisition* words, since no children

We are grateful to David Smillie for suggesting the corpus of words from which our stimuli were drawn. Reprint requests should be sent to David B. Boles, Department of Psychology, Illinois State University, Normal, Illinois 61761. S. Rogers' and W. Wymer's complete mailing address is: Department of Psychology, University of South Florida, Tampa, Florida 33620.

Table 1
Matching of the Word Sets

	Age of Acquisition					
	Early		Middle		Late	
	Mean	SD	Mean	SD	Mean	SD
Length in Letters	4.1	1.1	4.1	1.1	4.1	1.1
Length in Syllables	1.1	.4	1.1	.4	1.3	.5
Concreteness*	2.0	.6	1.7	.5	2.0	.8

*Maximum = 1.

had acquired them by the mean age of 20 months. It was assumed that all words were learned after 2 years, but in any case, if asymmetry is obtained for this set, it cannot be argued that the failure to obtain confirmed ages of acquisition impeaches the logic of the experiment. The words were: cart, comet, gem, hunt, jar, mug, pistol, and steam.

As far as was possible, the word sets were equated for mean length in letters, mean length in syllables, and mean concreteness. Concreteness was equated by having six naive adults rate a larger set of words for concreteness/abstractness on a scale from 1 to 7; the mean interjudge correlation across words was $r = +.47$. Table 1 gives the relevant statistics for each of the three word sets.

Words were constructed using bold uppercase type, placed on white card stock suitable for tachistoscopic viewing. Each card had a single digit (1-8) at visual fixation (the center of the tachistoscopic field), subtending 6 mm vertically and 5 mm horizontally, plus a single word to one or the other side of fixation, with the nearest end 25 mm from fixation. Words subtended 6 mm vertically and from 17 to 39 mm horizontally, depending on the particular word. However, the length of a particular word was identical whether it appeared to the left or the right of fixation and was always spaced the same distance from fixation. Note that although the use of horizontal words introduces display asymmetry (the beginnings of words are closer to fixation in the RVF than in the LVF), at least three sources of evidence indicate that this produces little or no effect on visual field main effects and interactions: (1) Horizontal and vertical words both produce RVF advantages, of comparable magnitude (Bradshaw & Gates, 1978, vs. Day, 1977; Mackavey, Curcio, & Rosen, 1975), (2) horizontal words may *not* produce significant asymmetry unless paired with a central fixation digit or another word in the opposite visual field (Boles, in press), and (3) asymmetry obtained with horizontal words interacts with a number of "hemispheric" variables, including subject's handedness (Bradshaw & Taylor, 1979; Schmueller & Goodman, 1979) and abstractness/concreteness or low/high imagery (Ellis & Shephard, 1974; Hines, 1976; Marcel & Patterson, 1978). Indeed, the Marcel and Patterson study is particularly problematic for any view that horizontal words produce artificial asymmetry, since there was zero asymmetry for high-imagery words.

Each of the eight words in each of the three sets appeared once in each visual field, producing a set of 48 stimulus cards.

Apparatus

The stimuli were shown in a Scientific Prototype three-channel card tachistoscope, in one channel and at a distance of 1.27 m. A second channel contained a fixation card, consisting of a single vertical line with a space in the middle sufficient to center the digit without overlapping it.

Procedure

A trial consisted of the experimenter's saying "ready" with the fixation line in view, followed after approximately 1 sec by the presentation of a stimulus card for 40 msec. At stimulus

offset, the fixation line reappeared. After the subject responded by recalling the digit and word as well as possible, a new stimulus card was inserted into the tachistoscope and the cycle was repeated. All 48 cards were shown in this manner in random order, and then the deck was reshuffled and the sequence was repeated; this produced two blocks of trials.

Subjects were instructed to fixate on the gap in the fixation line on the word "ready" and to repeat both the digit and the word if possible, the two being equally important. The central digit was used because in several reports (Boles, in press; McKeever & Huling, 1971; Olson, 1973), it has been found that a central fixation stimulus magnifies visual field asymmetry for the primary stimulus material, over the case in which only a single word appears. Thus, if there *are* differences in asymmetry between the age-of-acquisition conditions, this method should be maximally sensitive to them.

The responses of the subject were written down by the experimenter as they were given, along with a number that identified the stimulus card.

Subjects

Subjects were 22 New College students, 11 male and 11 female, and all were right-handed by self-report. They were paid for their participation in the approximately 1-h experiment.

RESULTS

As in previous reports, the central digit had to be recalled correctly for a word to also be scored as correct, a method that helps eliminate trials in which there was failure to fixate. The data were subjected to an age of acquisition (early, middle, late) $\times$ block (first, second) $\times$ visual field (left, right) $\times$ sex (female, male) ANOVA, with the first three factors varied within subjects.

There were significant main effects of visual field, block, and age [respectively, $F(1,20) = 28.91$, $p < .001$, $F(1,20) = 35.35$, $p < .001$; $F(2,40) = 14.44$, $p < .001$]. The RVT, as anticipated, produced better performance than the LVF (82.4% vs. 70.1%); 19 subjects were in this direction, 2 were in the opposite direction, and 1 showed no difference. There was also a practice effect, with higher recognition in the second block (81.4%) than in the first (71.2%). Late-acquisition words were more poorly recognized (67.9%) than either early-acquisition [78.2%; $t(21) = 3.06$, $p < .01$] or middle-acquisition words [82.6%; $t(21) = 4.93$, $p < .001$], and early-acquisition words were slightly more poorly recognized than middle-acquisition words [$t(21) = 2.12$, $p < .05$]. However, these age-of-acquisition effects were probably artifacts of word frequency. Mean Kučera-Francis (1967) frequencies for the early-, middle-, and late-acquisition sets were 73.3 ($s = 88.4$), 89.0 ($s = 145.8$), and 10.3 ($s = 9.1$), respectively. A post hoc analysis confirmed that frequency affected recognition, as did length in letters; thus, the correlation between frequency and percent correct recognition was $r(22) = +.41$ ($p < .05$) with length partialled out, and the correlation between length and recognition was $r(22) = -.66$ ($p < .001$), with frequency partialled out. Given the large frequency differences between word sets, this suggests that the age-of-acquisition effects are predictable on the basis of word frequency.

Table 2
Percent Correct in Each Visual Field for Each
of the Ages of Acquisition

	Age of Acquisition		
	Early	Middle	Late
RVF	83.7	89.2	74.1
LVF	72.7	76.1	61.6
Difference	11.0	13.1	12.5

Most important, there was no interaction of age $\times$ visual field [$F(2,40) < 1$], as shown in Table 2. The degrees of asymmetry in favor of the right field were 11.0%, 13.1%, and 12.5% for early-, middle-, and late-acquisition words, respectively. Since this null effect is of critical importance to the experimental hypothesis, a power analysis was conducted for the difference in asymmetry between early- and late-acquisition words. Using the conventional parameters of power = .80 and $\alpha = .05$ (two-tailed), it was found that the study had sufficient power to detect an interaction of 9.0%. In other words, given the obtained +12.5% RVF advantage for late-acquisition words, an asymmetry of +3.5% or less for early-acquisition words would have been detectably different. This is adequate sensitivity since (1) the age-of-acquisition hypothesis predicts zero asymmetry for early-acquisition words and (2) most previous studies reporting an interaction between visual field or ear and abstractness/concreteness (the phenomenon that the age-of-acquisition hypothesis was posited to explain) find a null or even slightly negative (LVF) asymmetry for concrete nouns (e.g., Day, 1977, 1979; Elman et al., 1981; McFarland et al., 1978). Thus, if the expected interaction were veridical, it should have been detected, and it was not. In addition, since word frequency did not correlate with asymmetry [$r(22) = -.24$], the null effect cannot be explained by differential frequency across word sets.

The only interactions to reach significance were age $\times$ block [$F(2,40) = 3.78$, $p < .05$] and visual field $\times$ sex [$F(1,20) = 5.25$, $p < .05$]. The former apparently reflects nothing more than a covariance of practice with difficulty, as the more difficult late-acquisition words showed a larger increase in percent correct over blocks (15.9%) than did the early-acquisition (7.7%) or middle-acquisition words (6.9%). On its surface, the latter indicates smaller asymmetry for females (LVF, 77.1%; RVF, 84.1%) than for males (63.2% vs. 80.6%). However, as a further investigation of the visual field $\times$ sex interaction, a correlation was calculated over subjects between the size of the visual field asymmetry and the total percent correct. This correlation was negative and significant [$r(20) = -.57$, $p < .01$],¹ indicating that as accuracy increased across subjects, asymmetry decreased. Since females tended to show higher accuracy than

males (80.6% vs. 71.9%), this finding suggests that the obtained interaction between visual field and sex may reflect little more than a ceiling effect on overall accuracy that limits measured asymmetry. Indeed, when a "laterality index" was subsequently calculated as asymmetry (right minus left) divided by total accuracy, which was itself found to be unrelated to total accuracy [$r(20) = .00$], the difference between the sexes disappeared [$t(20) = .89$].

Finally, mention might be made of an analysis of word and digit report order. A minority of reports (23.8%) were in the order word-digit, distributed equally across age-of-acquisition but not visual field conditions. In the LVF, the early-, middle-, and late-acquisition conditions accounted for 28.7%, 28.1%, and 27.6% of such reports, respectively, whereas the corresponding RVF conditions accounted for the remaining 5.2%, 5.4%, and 5.0%. Clearly, differential order of report is not responsible for the nonsignificant age $\times$ visual field interaction, but these results give some scope for challenging the visual field main effect. This is particularly true because the two potential sources of order-of-report artifact are distributed complexly across visual field and report order alternatives; these are (1) the report of the word after the digit, which might depress word recognition due to a fading stimulus trace, and (2) the reporting of stimuli in an "unnatural" order (such as word-digit when the stimuli appeared in the left-to-right order digit-word), which might depress word recognition in comparison with a more natural order.

Fortunately, there exists a conservative test of the visual field main effect that eliminates these potential artifacts. This is a comparison of LVF words reported in the order word-digit to RVF words reported in either order. The LVF stimuli are then subject to neither confound (the word is reported first, and in its "natural" order), whereas all RVF stimuli are subject to one or the other (a fading trace with digit-word reports, and an "unnatural" order with word-digit reports). Thirteen subjects were found to have made enough LVF word-digit reports to permit analysis, and in spite of the conservative nature of the comparison, a +9.6% RVF advantage was nevertheless obtained [$t(12) = 2.53$, $p < .05$]. Accordingly, it would seem that the visual field main effect is veridical.

DISCUSSION

No differences were found in RVF recognition superiority over the three ages of acquisition; words learned before the age of 2 years showed essentially the same asymmetry as those presumed to have been learned after the age of 2 years. The hypothesis that the young child has, in effect, a split brain predicts that no asymmetry would be found for words learned before age 2 years, so our results do not support the hypothesis.

Thus, we are in substantial agreement with the conclusions drawn by Ellis and Young (1977; Young & Ellis, 1980), even though we have reservations about their use of age-of-acquisition ratings and the mean age of acquisition they ascribed to their early-acquisition word set.

The notion that the young child has a split brain draws heavily on the idea that myelination reflects the earliest function in the nervous system. In addition to Gazzaniga (1974), other researchers (e.g., Bee & Mitchell, 1980; Galin, 1977; Lecours, 1975) also have assumed that until a neuron acquires its myelin sheath, it has little or no function. However, there are several points that bring this doctrine into question. First, Type C neurons in man *never* myelinate, and yet they have a function, conducting neural impulses slowly (P. M. Milner, 1970). Second, as early as 1929, it was recognized that neonatal rats are capable of a range of motor activity even though they possess nervous systems that at that point in development have virtually no myelin (Nash, 1970). Third, electrical stimulation studies show that both interhemispheric transmission and corpus callosum responsivity exist prior to the myelination of the callosum (Berry, 1974). And last, the visual cortex of neonatal kittens responds to stimulation of the optic nerve, which is unmyelinated at that point in development (Berry, 1974).

We do not dispute that myelination is a valid indicator of which neurons mature first (E. Milner, 1977; Nash, 1970); when used in the relative sense of comparing areas of the nervous system as to maturity, myelination serves as a very valuable index. In addition, it seems almost certain that the development of myelin alters the function of the neuron, speeding the conduction of the neural impulse and improving the cell's insulation (Cotman & McGaugh, 1980; Grafstein, 1963; P. M. Milner, 1970). But we do call into question the use of the myelin criterion as an absolute threshold for neural function, and we suggest that relatively slow, poorly insulated function becomes possible at some earlier point in development. In the present context, this may mean that the corpus callosum does have a function in the young child.

Finally, since the age-of-acquisition hypothesis has not been found to account for adult asymmetries in word recognition, it can be suggested that the focus should remain where several have placed it: on imagery as a possible explanation for right-hemisphere recognition of concrete words (Day, 1979; Seamon & Gazzaniga, 1973).

REFERENCES

- BEE, H. L., & MITCHELL, S. K. *The developing person: A life-span approach*. Harper & Row, 1980.
- BERRY, M. Development of the cerebral neocortex of the rat. In G. G. Gottlieb (Ed.), *Aspects of neurogenesis* (Vol. 2 of *Studies on the development of behavior and the nervous system*). New York: Academic Press, 1974.
- BOLES, D. B. Hemispheric interaction in visual field asymmetry. *Cortex*, in press.
- BRADSHAW, J. L., & GATES, E. A. Visual field differences in verbal tasks: Effects of task familiarity and sex of subject. *Brain and Language*, 1978, 5, 166-187.
- BRADSHAW, J. L., & TAYLOR, M. J. A word-naming deficit in nonfamilial sinistrals? Laterality effects of vocal responses to tachistoscopically presented letter strings. *Neuropsychologia*, 1979, 17, 21-32.
- COTMAN, C. W., & MCGAUGH, J. L. *Behavioral neuroscience: An introduction*. New York: Academic Press, 1980.
- DAY, J. Right-hemisphere language processing in normal right-handers. *Journal of Experimental Psychology: Human Perception and Performance*, 1977, 3, 518-528.
- DAY, J. Visual half-field word recognition as a function of syntactic class and imageability. *Neuropsychologia*, 1979, 17, 515-519.
- ELLIS, H. D., & SHEPHERD, J. W. Recognition of abstract and concrete words presented in the left and right visual fields. *Journal of Experimental Psychology*, 1974, 103, 1035-1036.
- ELLIS, H. D., & YOUNG, A. W. Age-of-acquisition and recognition of nouns presented in the left and right visual fields: A failed hypothesis. *Neuropsychologia*, 1977, 15, 825-828.
- ELMAN, J. L., TAKAHASHI, K., & TOHSAKU, Y. Lateral asymmetries for the identification of concrete and abstract Kanji. *Neuropsychologia*, 1981, 19, 407-412.
- GALIN, D. Lateral specialization and psychiatric issues: Speculations on development and the evolution of consciousness. *Annals of the New York Academy of Sciences*, 1977, 299, 397-411.
- GAZZANIGA, M. S. Cerebral dominance viewed as a decision system. In S. J. Dimond and J. G. Beaumont (Eds.), *Hemisphere function in the human brain*. New York: Wiley, 1974.
- GRAFSTEIN, B. Postnatal development of the transcallosal evoked response in the cerebral cortex of the cat. *Journal of Neurophysiology*, 1963, 26, 79-99.
- HINES, D. Recognition of verbs, abstract nouns, and concrete nouns from the left and right visual fields. *Neuropsychologia*, 1976, 14, 211-216.
- KUČERA, H., & FRANCIS, W. N. *Computational analysis of present-day American English*. Providence, R.I.: Brown University Press, 1967.
- LECOURS, A. Myelogenetic correlates of the development of speech and language. In E. H. Lenneberg & E. Lenneberg (Eds.), *Foundations of language development: A multidisciplinary approach*. New York: Academic Press, 1975.
- MACKAVEY, W., CURCIO, F., & ROSEN, J. Tachistoscopic word recognition performance under conditions of simultaneous bilateral presentation. *Neuropsychologia*, 1975, 13, 27-33.
- MARCEL, A. J., & PATTERSON, K. E. Word recognition and production: Reciprocity in clinical and normal studies. In J. Requin (Ed.), *Attention and performance VII*. Hillsdale, N.J.: Erlbaum, 1978.
- MCFARLAND, K., MCFARLAND, M. L., BAIN, J. D., & ASHTON, R. Ear differences of abstract and concrete word recognition. *Neuropsychologia*, 1978, 16, 555-561.
- McKEEVER, W. F., & HULING, M. D. Lateral dominance in tachistoscopic word recognition performances obtained with simultaneous bilateral input. *Neuropsychologia*, 1971, 9, 15-20.
- MILNER, E. CNS maturation and language acquisition. In H. Whitaker & H. A. Whitaker (Eds.), *Studies in neurolinguistics* (Vol. 1). New York: Academic, 1977.
- MILNER, P. M. *Physiological psychology*. New York: Holt, Rinehart & Winston, 1970.
- NASH, J. *Developmental psychology: A psychobiological approach*. Englewood Cliffs, N.J.: Prentice-Hall, 1970.
- NELSON, C. Structure and strategy in learning to talk. *Society for Research in Child Development Monographs*, 1973, 38, Nos. 1-2.
- OLSON, M. E. Laterality differences in tachistoscopic word recognition in normal and delayed readers in elementary school. *Neuropsychologia*, 1973, 11, 343-350.
- SCHMULLER, J., & GOODMAN, R. Bilateral tachistoscopic per-

ception, handedness, and laterality. *Brain & Language*, 1979, **8**, 81-91.

SEAMON, J. G., & GAZZANIGA, M. S. Coding strategies and cerebral laterality effects. *Cognitive Psychology*, 1973, **5**, 249-256.

SUGISHITA, M. Mental association in the minor hemisphere of a commissurotomy patient. *Neuropsychologia*, 1978, **16**, 229-232.

YOUNG, A. W., & ELLIS, H. D. Ear asymmetry for the perception of monaurally presented words accompanied by binaural white noise. *Neuropsychologia*, 1980, **18**, 107-110.

NOTE

1. Perhaps more appropriately, $r(9) = -.07$ for females (n.s.), and $r(9) = -.75$ for males ($p < .01$). Clearly, if male accuracy had been as high as female accuracy, male asymmetry would have been diminished.

(Manuscript received Month 00, 1987;
revision accepted for publication August 3, 1982.)