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Hemispheric Differences in Grammatical Class

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Although a number of studies have examined lexical asymmetries in hemispheric processing, few have systematically investigated differences between nouns and verbs. Lateralization effects of grammatical class were examined by presenting nouns and verbs of both high and low frequency to either the right or left visual field. Results from both a noun/verb categorization and a lexical decision task revealed a significant visual field by grammatical class interaction. Further analyses revealed that verbs were processed faster in the left compared to the right hemisphere, while there was no hemispheric advantage for the processing of nouns. The present study provides new evidence for the role of grammatical class in lexical processing. © 1999 Academic Press

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The salience of hemispheric asymmetries in the processing of grammatical class is explored in this article. Anatomically, there is evidence for hemispheric asymmetries in adults, in infants, and even in the fossil record (Geschwind & Galaburda, 1987). Behaviorally, these asymmetries have also been noted (for reviews, see Hellige, 1993; Beeman & Chiarello, 1998). Traditionally, the left hemisphere was characterized as dominant, focused on language, while the right hemisphere was subordinate and mute. Modifications of this view emphasized differences in the manner in which the two hemispheres treat incoming information: processing in the left hemisphere was more analytic, sequential, and involved in linguistic analysis whereas the right hemisphere was holistic, with acute visual spatial skills, and sensitive to processing melody and intonation. A more contemporary characterization

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suggests a distinction based on computational styles, with fine coding of information and categorical judgments attributed to the left hemisphere and coarse coding and coordinate analyses to the right hemisphere (e.g., Beeman, 1994; Kosslyn et al., 1989). In all conceptualizations, it is clear that the right and left hemispheres function differently.

A much debated question regarding hemispheric processing of *language* is whether there are differences in lexical processing—namely, whether both hemispheres have access to similar lexicons. Early research suggested that the right hemisphere accessed only a small set of high frequency, highly imageable, concrete, content words. However, some recent research has shown a different pattern of results. Chiarello (1988), for example, concludes that word frequency effects appear to be constant across the hemispheres. Moreover, when word frequency is controlled, there are few differences in the processing of content and function words. Neither have consistent differences been shown in terms of the lexical variables of abstractness and imageability. Overall, then, more recent research seems to question a simplistic notion of unequal lexicons across the hemispheres based on frequency, imageability or content/function class distinctions.

A potentially more productive characterization of hemispheric differences in lexical processing may be found in differences in grammatical class—specifically, between nounds and verbs. Rarely, however, have noun/verb distinctions been examined in processing. Most psycholinguistic studies use only nouns, or do not analyze nouns and verbs separately.

Some of our own research has scrutinized the noun–verb distinction in more detail, investigating a number of distinguishing characteristics of nouns in contrast to verbs. Sereno and Jongman (1990) and Sereno (1994) obtained data supporting a phonological distinction between nouns and verbs in English. A lexical analysis of the Brown Corpus (Francis & Kucera, 1982) revealed a skewed distribution in which the syntactic classes of noun and verb are distinguished in terms of the phonological classification of their stressed vowel. This distinction was shown as well to have perceptual consequences, with subjects processing nouns with back vowels and verbs with front vowels faster, a finding that generalized over tasks (lexical decision, noun/verb categorization). These results suggest that subjects are sensitive to grammatical class differences and that syntactic class may be a parameter that structures lexical space.

A number of studies have also examined lexical stress differences between nouns and verbs. Lexical analysis of English has revealed that most bisyllabic nouns in English are forestressed whereas most bisyllabic verbs are backstressed (Kelly, 1988; Kelly & Bock, 1988; Sereno, 1986). Sereno and Jongman (1995) analyzed English bisyllabic words that can be used as either a noun or a verb (words such as *answer* or *design*). They found consistent acoustic differences in speakers’ production of these syntactically ambiguous words contingent upon their function as a noun or verb.

Significant differentiation between nouns and verbs at a number of linguistic levels raises the possibility of detectable neuropsychological differences in processing. A few studies in the late 1970s did compare nouns and verbs experimentally across visual field. Words were varied in terms of imageability, concreteness, grammatical class, or frequency, using either lexical decision or naming tasks.

In particular, Hines (1976) evaluated visual half-field recognition for high and low frequency verbs, abstract nouns, and concrete nouns. His most significant finding was an interaction between visual field, word class, and frequency. Subjects more easily recognized *abstract* high frequency nouns presented in the right visual field and *concrete* high frequency nouns in the left visual field. Unfortunately, there were a number of problems with these data. As Hines himself noted in a later study (1977), the sample of words used in these experiments could not be generalized. Also, low levels of accuracy obtained, possibly due to short stimulus exposure time (20 ms).

In a later study that included equal numbers of nouns and verbs, Shanon (1979) reported no significant interactions. However, field presentation was not balanced. Day (1979) also conducted a similar experiment, but added adjectives as a third grammatical class and controlled for visual field presentation. Within each of the noun, verb, and adjective groups, half of the words were high imagery words and half were low imagery words. Results suggested a right visual field advantage for low imagery nouns and adjectives and high and low imagery verbs, but not for high imagery nouns and adjectives. Day theorized that the right hemisphere may be capable only of recognizing words high in imagery. However, no statistically significant interaction between visual field and syntactic class was reported.

Although some of these reports claimed that syntactic class affected hemispheric processing, caution must be used in interpreting the results. These studies were problematic in several respects. In many cases, stimuli did not appear in both visual fields. Error rates of approximately 50% were often reported, and reaction times were on the order of 1500–2000 ms. Finally, some authors claimed an effect of visual field without reporting the crucial interaction statistics. These previous studies thus cannot either substantiate or refute a claim for lateralization of grammatical class.

While more recent studies have shown that there are no significant differences in imageability or frequency between the hemispheres (for a review, see Chiarello, 1988), grammatical class differences have not been reexamined under rigid testing procedures, and that was the incentive for the present study. Based on prior results from our laboratory, we fully expected that reaction times for nouns would be shorter than those for verbs in either visual field (e.g., Sereno & Jongman, 1997). The present study sought to extend this finding by investigating whether these grammatical class differences are lateralized. Two tasks were used to determine whether the effects were generalizable.

METHODS

Participants

Thirty-eight college students (15 male and 23 female) participated in the noun/verb categorization experiment. Twenty-four college students (12 male and 12 female) participated in the lexical decision experiment. All subjects were right-handed native speakers of English. Up to 4 subjects were tested at a time.

Materials

Forty-four four-letter words were selected as stimuli (see Appendix). Half of the words were exemplary nouns, with no occurrences as verbs in the Brown Corpus; and half of the words were exemplary verbs, with no occurrences as nouns (Francis & Kucera, 1982). The nouns and verbs were also equally divided into high and low frequency groups. Noun and verb groups were matched for frequency (mean log frequency of high frequency nouns and verbs was 2.38 and 2.27, respectively; mean log frequency of low frequency nouns and verbs was .98). All stimuli were monosyllabic except for one bisyllabic stimulus per group (high frequency nouns, low frequency nouns, high frequency verbs, low frequency verbs).

For the lexical decision experiment, forty-four four-letter nonwords were also used (see Appendix). Forty nonword stimuli were monosyllabic and 4 were bisyllabic.

Design and Procedure

Two tasks were used: a noun/verb categorization task and a lexical decision task. For noun/verb categorization, participants were to decide as quickly as possible whether each stimulus was a noun or verb. A response was recorded by a button press with the right index finger centered between the noun and verb buttons. For the lexical decision task, participants were to decide as quickly as possible whether each stimulus was a word or not. A response was recorded by a button press with the right index finger centered between the word and the nonword buttons. Button order for both noun/verb categorization and lexical decision was counterbalanced across subjects.

Stimulus timing was controlled by a Swan PC running BLISS software (Mertus 1989). Each trial started with a central fixation cross presented for 500 ms. Immediately following fixation, stimuli were presented unilaterally for 183 ms (screen refresh rate is 60 Hz) in lower case letters in horizontal orientation. Each stimulus was presented twice: once in the left visual field and once in the right visual field. Order of presentation was randomized. The center of each word was displaced 2.5° to the left or right of the center of the computer screen. Stimuli were presented at a fixed rate with an SOA of 2.5 s. Response time was measured from the onset of the target word until a noun/verb categorization or lexical decision response was made.

RESULTS

Noun/Verb Categorization

Results consisted of reaction time and error data. Both subject and item analyses were conducted. We anticipated a possible gender effect; however, a first analysis revealed no main effects or interactions involving participant gender. Nor were there any main effects or interactions involving button order. Hence, these variables were not considered in subsequent analyses.

A repeated-measures ANOVA with Visual Field, Frequency, and Grammatical Class was conducted on both the reaction time and the error data. For the reaction time data, a main effect of Visual Field ([$F1(1,37) = 5.23$, $MS_e = 1868$, $p = .028$]; [$F2(1,40) = 5.57$, $MS_e = 637$, $p = .023$]) indicated that responses were significantly faster to stimuli presented to the right visual field (746 ms) compared to the left visual field (757 ms). The literature (e.g., Hellige, 1993; Bryden, 1982) has consistently shown that when words are briefly presented to the left or right of fixation, performance is often asymmetrical, with faster and more accurate responses to stimuli presented in the right visual field. The interpretation of this typical result ranges from a scanning bias to the processing style of the hemisphere that is initially activated.

A main effect of Frequency ([$F1(1,37) = 31.30$, $MS_e = 2364$, $p = .000$]; [$F2(1,40) = 11.22$, $MS_e = 2063$, $p = .002$]) revealed that responses were significantly faster to high frequency stimuli (736 ms) than to low frequency stimuli (767 ms). This is also an expected effect, since high frequency stimuli had an average frequency of occurrence of approximately 300 per million and low frequency stimuli 10 per million. This frequency effect was evident in both the right and the left visual fields.

A main effect of Grammatical Class ([$F1(1,37) = 8.12$, $MS_e = 4896$, $p = .007$]; [$F2(1,40) = 5.00$, $MS_e = 2063$, $p = .031$]) indicated that nouns (740 ms) were responded to significantly faster than verbs (763 ms), a result we have consistently obtained in our experiments. Sereno and Jongman (1997) attribute this effect to differences in inflectional structure between nouns and verbs in English—nouns occur more frequently as uninflected forms.

In addition to the main effect of Grammatical Class, there was also a Grammatical Class by Frequency interaction ([$F1(1,37) = 18.29$, $MS_e = 1823$, $p = .001$]; [$F2(1,40) = 5.21$, $MS_e = 2063$, $p = 0.28$]). As shown in Fig. 1, nouns and verbs differed across frequency of occurrence. High frequency nouns were 44 ms faster than high frequency verbs while response times to low frequency stimuli showed only a nonsignificant 2-ms difference. If frequency differences associated with inflectional differences produce this grammatical class effect, differences should be more prominent in high frequency words because absolute differences in uninflected frequency are relatively greater for high frequency stimuli. This is indeed the pattern that obtained.

Finally, the most intriguing finding of the present study was the significant interaction between Visual Field and Grammatical Class ([$F1(1,37) = 9.57$, $MS_e = 1530$, $p = .004$]; [$F2(1,40) = 6.57$, $MS_e = 637$, $p = .014$]). As shown in Fig. 2, nouns and verbs differed across the two hemispheres. Simple effects analyses revealed that response times to verbs presented to the right visual field were 25 ms faster compared to the left visual field. For nouns, there was a nonsignificant 3-ms difference between hemispheres.

Recall that our earlier study (Sereno & Jongman, 1997) indicated that overall grammatical class differences may be due to simple frequency differ-

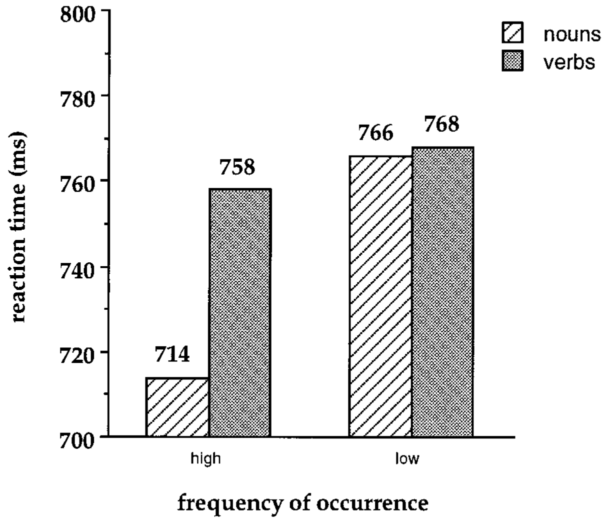

FIG. 1. Response latencies (in ms) to nouns and verbs as a function of frequency of occurrence in a noun/verb categorization task.

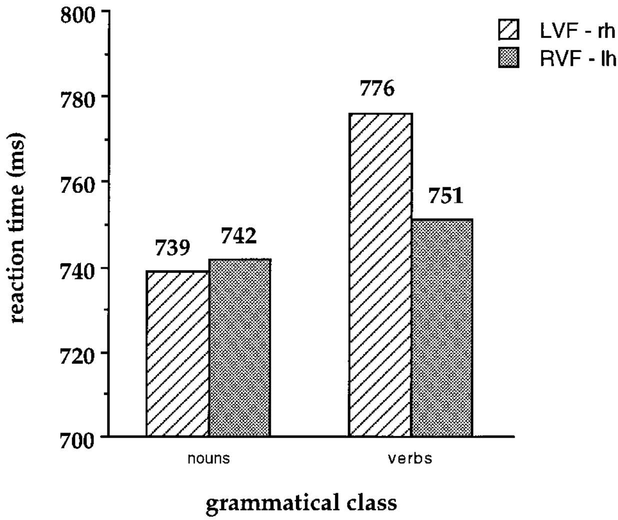

FIG. 2. Response latencies (in ms) to nouns and verbs as a function of visual field in a noun/verb categorization task. (LVF-rh indicates left visual field presentation to the right hemisphere and RVF-lh indicates right visual field presentation to left hemisphere.)

ences of uninflected forms. However, in the present study, grammatical class differences *across hemispheres* cannot be attributed to frequency since frequency of occurrence differences did not turn up across hemispheres, either by interacting with Visual Field or as a three-way interaction with Visual Field and Grammatical Class. Grammatical class alone showed a significant processing difference across hemispheres.

In order to determine whether imageability and/or concreteness affected the present results, ANCOVAs were conducted with imageability and/or concreteness as covariates. Imageability and concreteness norms were taken from the MRC Psycholinguistic Database (Coltheart, 1981; Wilson, 1988) or from the recent imageability ratings of nouns and verbs (Chiarello, Shears, & Lund, 1999). In all analyses, the interaction of Visual Field by Grammatical Class still obtained, suggesting that neither imageability nor concreteness was responsible for the laterality effects involving grammatical class.

A repeated-measures ANOVA with Visual Field, Frequency, and Grammatical Class was conducted on the error data. Two main effects were observed. A main effect of Frequency ([$F1(1,37) = 15.06$, $MS_e = 11$, $p = .001$]; [$F2(1,40) = 6.59$, $MS_e = 38$, $p = .014$]) indicated that there were more errors to low frequency stimuli (148 errors) than to high frequency stimuli (90 errors). A main effect of Grammatical Class ([$F1(1,37) = 9.08$, $MS_e = 8$, $p = .005$]; [$F2(1,40) = 4.90$, $MS_e = 28$, $p = .033$]) revealed that there were more errors to verb stimuli (144 errors) than to noun stimuli (94 errors). The error results are consistent with the reaction time data.

Lexical Decision

Results consisted of reaction time and error data. Both subject and item analyses were conducted. A first analysis revealed no main effects or interactions involving participant gender or button order. Hence, these variables were not considered in subsequent analyses.

A repeated-measures ANOVA with Visual Field, Frequency, and Grammatical Class was conducted on both the reaction time and error data. For the reaction time data, a main effect of Visual Field ([$F1(1,23) = 2.92$, $MS_e = 4122$, $p = .101$]; [$F2(1,40) = 7.08$, $MS_e = 806$, $p = .011$]) (showing a trend for the subject analysis and a significant effect in the item analysis) indicated that responses were faster to stimuli presented to the right visual field (649 ms) compared to stimuli in the left visual field (666 ms). This visual field effect is similar to the effect found for noun/verb categorization as well as other hemispheric studies.

A main effect of Frequency ([$F1(1,23) = 94.13$, $MS_e = 2028$, $p = .000$]; [$F2(1,40) = 17.89$, $MS_e = 6083$, $p = .000$]) revealed that responses were significantly faster to high frequency stimuli (626 ms) than to low frequency stimuli (691 ms). This effect is again similar to the noun/verb categorization

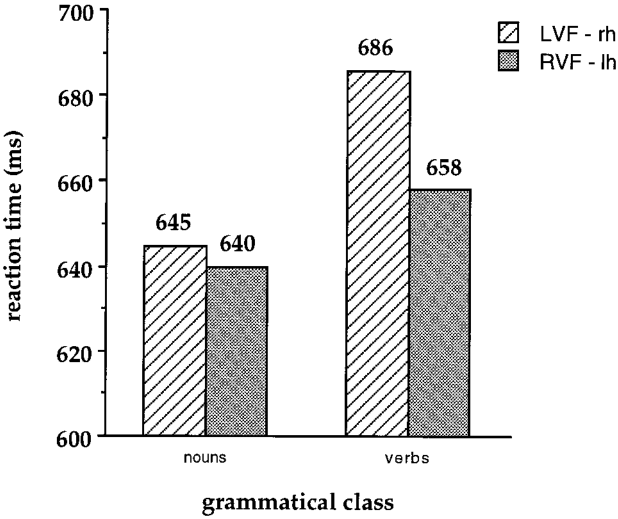

FIG. 3. Response latencies (in ms) to nouns and verbs as a function of visual field in a lexical decision task. (LVF-rh indicates left visual field presentation to the right hemisphere and RVF-lh indicates right visual field presentation to left hemisphere.)

results and was expected. This frequency effect was evident in both the left and the right visual fields.

A main effect of Grammatical Class ([$F1(1,23) = 22.63$, $MS_e = 1789$, $p = .000$]; [$F2(1,40) = 4.85$, $MS_e = 6083$, $p = .034$]) indicated that nouns (643 ms) were responded to significantly faster than verbs (672 ms), a result also similar to the noun/verb categorization data.

The only interaction that obtained and the most intriguing finding of the present lexical decision experiment was the significant interaction between Visual Field and Grammatical Class ([$F1(1,23) = 15.31$, $MS_e = 500$, $p = .001$]; [$F2(1,40) = 3.34$, $MS_e = 806$, $p = .075$]). As shown in Fig. 3, nouns and verbs differed across the two hemispheres. Simple effects analyses revealed that response times to verbs presented to the right visual field were significantly faster (28 ms) compared to the left visual field. For nouns, there was a nonsignificant 5-ms difference between hemispheres.

In order to determine whether imageability and/or concreteness affected the present results, ANCOVAs were conducted with imageability and concreteness as covariates. Results indicated that the interaction of Visual Field by Grammatical Class still obtained.

A repeated measures ANOVA with Visual Field, Frequency, and Grammatical Class was conducted on the error data. Three main effects were observed. A main effect of Frequency ([$F1(1,23) = 27.32$, $MS_e = 1$, $p = .001$]; [$F2(1,40) = 9.06$, $MS_e = 6$, $p = .005$]) indicated that there were more errors to low frequency stimuli (91 errors) than to high frequency stimuli (18 errors). A main effect of Grammatical Class ([$F1(1,23) = 20.86$, $MS_e = 1$, $p = .000$]; [$F2(1,40) = 5.14$, $MS_e = 6$, $p = .029$]) revealed that there were more errors to verb stimuli (82 errors) than to noun stimuli (27 errors). The only other significant finding was a Grammatical Class by Frequency interaction which was significant for subjects but did not reach significance in the item analysis ([$F1(1,23) = 10.59$, $MS_e = 1$, $p = .003$]; [$F2(1,40) = 2.59$, $MS_e = 6$, $p = .116$]). The error results are consistent with the reaction time data.

Task Comparison

A comparison of the noun/verb categorization and the lexical decision data was also conducted. A repeated-measures ANOVA with Task, Visual Field, Frequency, and Grammatical Class was conducted for both the reaction time and the error data. The pattern of results is very similar to the results obtained individually for the noun/verb categorization and lexical decision tasks.

As expected, there were main effects of Frequency ([$F1(1,60) = 116.97$, $MS_e = 2235$, $p = .000$]; [$F2(1,80) = 28.52$, $MS_e = 4073$, $p = .000$]), Grammatical Class ([$F1(1,60) = 21.40$, $MS_e = 3705$, $p = .000$]; [$F2(1,80) = 9.17$, $MS_e = 4073$, $p = .003$]), and Visual Field ([$F1(1,60) = 7.96$, $MS_e = 2731$, $p = .006$]; [$F2(1,80) = 12.65$, $MS_e = 722$, $p = .001$]). Across both tasks, response times to high frequency stimuli (681 ms) were faster than to low frequency stimuli (729 ms), response times to nouns (692 ms) were faster than to verbs (718 ms), and response times to stimuli in the right visual field (698 ms) were faster compared to stimuli in the left visual field (712 ms). A main effect for Task was also found ([$F1(1,60) = 15.81$, $MS_e = 65403$, $p = .000$]; [$F2(1,80) = 89.37$, $MS_e = 4073$, $p = .000$]), with lexical decision responses (657 ms) significantly faster than noun/verb categorization responses (752 ms).

Most relevant for the present study, there was a significant interaction between Visual Field and Grammatical Class ([$F1(1,60) = 18.22$, $MS_e = 1135$, $p = .000$]; [$F2(1,80) = 9.42$, $MS_e = 722$, $p = .003$]). In fact, this interaction is stronger than in the individual task analyses, and significant in both subject and item analyses. Nouns and verbs are processed differently in the two visual fields. Moreover, this effect does not interact with task. Simple effects analyses revealed that response times to verbs presented to the right visual field were on average 26 ms faster compared to the left visual field. For nouns, there was a nonsignificant 1-ms difference between hemispheres. Grammatical class shows a significant processing difference across hemispheres.

There was a significant Task by Frequency interaction ([$F1(1,60) = 13.37$, $MS_e = 2235$, $p = .001$]; [$F2(1,80) = 3.88$, $MS_e = 4073$, $p = .052$]). As shown in Fig. 4, high and low frequency stimuli differed across task. High

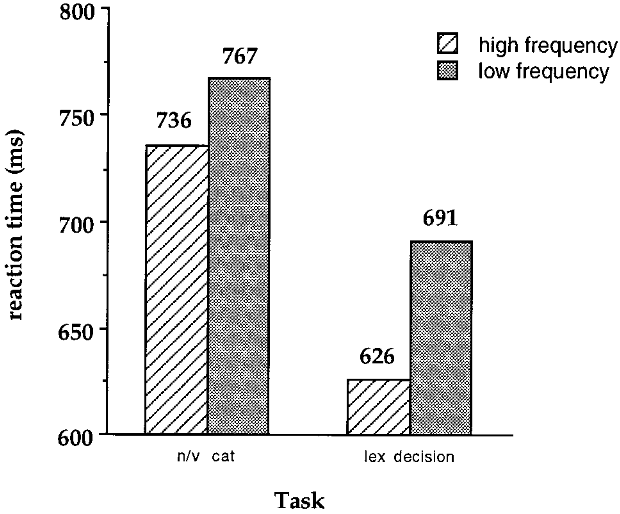

FIG. 4. Response latencies (in ms) to high and low frequency stimuli in a noun/verb categorization and lexical decision task.

frequency words were responded to 31 ms faster than low frequency words in the noun/verb categorization task while in the lexical decision task response times to high frequency words showed a 65-ms facilitation over low frequency words. Frequency differences are exaggerated in the lexical decision task compared to the categorization task.

The only other interaction was a Task by Frequency by Grammatical Class interaction which was significant in the subject analysis and showed a trend in the item analysis ([$F1(1,60) = 12.51$, $MS_e = 1531$, $p = .001$];[$F2(1,80) = 3.13$, $MS_e = 4073$, $p = .081$]). As shown in Fig. 5, high and low frequency nouns and verbs differed across task. In general, for noun/verb categorization, greater frequency differences were observed for nouns compared to verbs while in lexical decision greater frequency differences were observed for verbs compared to nouns. Task variables seem to play some role in grammatical class and frequency effects. It is interesting to note that none of these effects interacted with visual field.

A repeated-measures ANOVA with Task, Visual Field, Frequency, and Grammatical Class was conducted on the error data. There was a main effect of Frequency ([$F1(1,60) = 45.54$, $MS_e = 1$, $p = .000$]; [$F2(1,80) = 15.62$, $MS_e = 6$, $p = .000$]) and Grammatical Class ([$F1(1,60) = 28.21$, $MS_e = 1$, $p = .000$]; [$F2(1,80) = 10.04$, $MS_e = 6$, $p = .002$]). Across both tasks, there were more errors for low frequency stimuli (239 errors) than for high frequency stimuli (108 errors) and there were more errors for verb stimuli (226 errors) than for noun stimuli (121 errors). A main effect for Task was

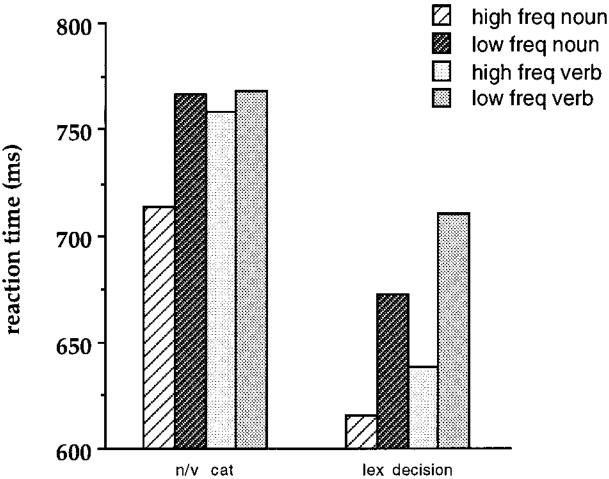

FIG. 5. Response latencies (in ms) to high and low frequency nouns and high and low frequency verbs in a noun/verb categorization and lexical decision task.

also found ([$F1(1,60) = 5.62$, $MS_e = 1$, $p = .021$]; [$F2(1,80) = 15.15$, $MS_e = 6$, $p = .000$]), with fewer errors for lexical decision (109 errors) compared to noun/verb categorization (238 errors). The only other significant effect was a Task by Frequency by Grammatical Class interaction ([$F1(1,60) = 10.02$, $MS_e = 1$, $p = .002$]; [$F2(1,80) = 3.85$, $MS_e = 6$, $p = .053$]), similar to the reaction time effect. For the noun/verb categorization task, there was a sizable difference in the number of errors between high (26 errors) and low (68 errors) frequency nouns compared to high (64 errors) and low (80 errors) frequency verbs. In lexical decision, this pattern was reversed, with little difference in high (5 errors) and low (22 errors) frequency nouns and a sizeable difference in high (13 errors) and low (69 errors) frequency verbs.

DISCUSSION

The present experiment demonstrates differences in the processing of nouns and verbs across the hemispheres. These effects show up for both the noun/verb categorization task as well as the more traditional lexical decision task. Further analyses for both tasks revealed that there were significant processing differences across hemispheres for verbs but not for nouns. Response times to verbs presented to the right visual field were on average 26 ms faster compared to verbs presented to the left visual field while noun stimuli showed only a 1-ms difference across visual fields. The lack of significant interactions with visual field (except for grammatical class) and additional analyses revealing that imageability and concreteness cannot account for the observed hemispheric differences further support a critical role for grammatical class as the relevant variable.

In addition to the grammatical class interaction, main effects of visual field (stimuli presented to the right visual field faster compared to the left visual field), frequency (high frequency stimuli faster than low frequency stimuli), and grammatical class (nouns faster than verbs) were observed. These effects showed up across both tasks despite a significant main effect of task, with lexical decision latencies 95 ms faster than noun/verb categorization times. The similarity of effects across the two tasks in the present experiment and also in previous experimental manipulations (Sereno & Jongman, 1990) suggests that the results obtained are robust and are not simply the result of post-access processes associated with lexical decision. The noun/verb categorization task, although slower than lexical decision, seems to be a possible alternative task for investigating language processing.

There was also a Task by Frequency interaction, with differences between high and low frequency stimuli larger in lexical decision compared to the noun/verb categorization task. Exaggerated effects of frequency in lexical decision have been observed previously (Balota & Chumbley, 1984; Besner & McCann, 1987), suggesting a role of a familiarity dimension in the decision component of lexical decision. This post-access component seems to be less influential in noun/verb categorization.

The only other significant finding was an interaction between Task, Frequency, and Grammatical Class, with differences showing up in the noun/verb categorization task between high and low frequency nouns but not for high and low frequency verbs while in lexical decision the differences between high and low frequency verbs were larger than those between high and low frequency nouns.

The most intriguing implication of the present findings concerns the overall organization of brain systems for language. The findings lend support to the notion that nouns are processed differently than verbs. Such a conclusion is supported by recent ERP studies noting marked neural dissociations between nouns and verbs across both hemispheres (Koenig & Lehmann, 1996; Molfese, Burger-Judisch, Gill, Golinkoff & Hirsch-Pasek, 1996).

Differences in the processing of nouns and verbs have also been shown within the left hemisphere in brain-damaged patients. These studies (e.g., Damasio & Tranel, 1993; Koenig, Wetzel, & Caramazza, 1992; Miceli, Silveri, Nocentini, & Caramazza, 1988; Miceli, Silveri, Villa, & Caramazza, 1984; Zingeser & Berndt, 1988, 1990) have documented aphasia patients with relatively selective noun or verb impairments. Specifically, agrammatic aphasics show deficits in verb retrieval, while anomic aphasics show deficits in noun retrieval. These selective deficits in processing are sometimes restricted to a single output modality, that is, spoken versus written output (Caramazza & Hillis, 1991). Recently, Damasio, Grabowski, Tranel, Hickwa, and Damasio (1996) have begun to investigate the implications of such an organization in normal unimpaired individuals. In a PET word retrieval experiment, Damasio et al. showed differential activation of brain sites for categories of nouns. These results suggest some form of categorical organization for grammatical class at the lexical level of representation.

The present set of experiments also document differences in the processing of nouns and verbs. However, the data reported here show up as differences across the hemispheres rather than within a hemisphere. The claim of processing differences across the hemispheres is directly supported by recent functional neuroimaging data (Pugh et al., 1997), suggesting distinct lateralized brain regions for the processing of nouns and verbs. In the Pugh et al. (1997) study, noun and verb differences were observed in the superior temporal gyrus region, and smaller effects show up in inferior frontal gyrus and extrastriate regions. Verbs were associated with greater left hemisphere activation compared to nouns while nouns showed a somewhat greater right hemisphere involvement. These differences were observed in both a lexical decision and a naming task. This study further supports the present hypothesis by indicating a relatively greater left hemisphere involvement in the processing of verbs relative to nouns.

Support for a hemispheric role in lexical organization may also be gained from investigating split-brain patients (see, for example, Baynes, 1990). In split-brain patients, the neural pathway which connects the two hemispheres is severed in order to minimize the transfer of epileptic seizures. Preliminary data from one patient show faster processing of verbs in the left hemisphere, similar to the present results with an unimpaired population.[1]

In sum, the present data from unimpaired individuals, additional results from impaired populations, and recent imaging results provide initial evidence for the hypothesis that lexical knowledge is organized in the brain such that representations of different grammatical categories are processed by widely distributed brain structures or mechanisms.

[1] These data were collected in collaboration with Kathy Baynes. Additional patients are being tested to corroborate these results.

APPENDIX

year	come	bist	lurt
girl	grow	blun	meap
door	send	bolf	nart
town	seek	chal	norb
wife	fail	corf	opet
food	join	cred	pish
tree	hang	dilt	plam
hair	save	doot	plef
poem	sing	epuk	poin
item	deny	feng	posk
hill	tend	fint	sarb
pony	obey	flom	sipe
soup	soak	ganu	smed
wart	chew	gorf	spet
bulb	bake	gret	surp
wolf	pave	hoke	trep
crib	lurk	ikol	troz
worm	stun	jine	visp
goat	veer	kade	vook
dime	mend	kerf	vorg
mule	weld	klat	zear
hoop	shun	lufe	zill

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