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RAPID COMMUNICATION

Linguistic and Nonlinguistic Priming in Aphasia

Elizabeth Bates

University of California, San Diego

Paola Marangolo and Luigi Pizzamiglio

Santa Lucia Hospital, University of Rome ''La Sapienza,'' Rome, Italy

and

Frederic Dick

University of California, San Diego

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Studies of real-time processing in aphasia suggest that linguistic symptoms may be due to deficits in activation dynamics rather than loss of linguistic knowledge. To investigate the domain specificity of such processing deficits, we compared performance by Italian-speaking fluent aphasics, nonfluent aphasics, and normal controls in a linguistic priming task (grammatical gender) with their performance in a color-priming task that requires no verbal mediation. Normal or larger than normal color-priming effects were demonstrated in both aphasic groups. Gender priming did not reach significance in either group, even though the patients displayed above-chance sensitivity to gender class and gender agreement in their accuracy scores. The demonstration of spared gender knowledge despite impaired gender priming underscores the utility of on-line techniques in the study of aphasia. The demonstration of spared color priming suggests that priming deficits in aphasia are either (1) specific to speech and language or (2) specific only to those sensorimotor and attentional processes that language shares with other nonlinguistic systems. © 2001 Academic Press

Although there is still no consensus regarding the functional bases of linguistic symptoms in aphasia, most investigators now agree that a full account will require research on the processes by which linguistic representations are activated in real time (e.g., Blumstein & Milberg, 2000; Friederici, 1995; Hagoort, Brown, & Osterhout, 1999; Marslen-Wilson & Tyler, 1997; Zurif, Swinney, Prather, Solomon, & Bushnell, 1993). Investigators have used linguistic priming techniques to determine whether patients can exploit semantic, phonological, or grammatical context to recognize target words. If priming is reduced or fails to appear, the disruption is usually

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Address correspondence and reprint requests to Elizabeth Bates, Center for Research in Language 0526, University of California, San Diego, 9500 Gilman Drive, La Jolla, California, 92093. E-mail: bates@crl.ucsd.edu.

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attributed to damage within the linguistic system. If priming is normal, investigators conclude instead that the linguistic system is intact, at least at some level (e.g., procedural but not declarative knowledge—Knowlton, Ramus, & Square, 1992).

The present study was designed to investigate the domain specificity of priming deficits in aphasia. Are abnormal priming profiles specific to language? Or do they reflect more general disruptions in processing, with analogous effects in nonlinguistic domains? To address these questions, we tested fluent and nonfluent aphasic patients on a color-priming task that does not require verbal mediation, but shares many task demands and response characteristics with linguistic priming techniques. If patients showed disruptions in color priming, then we might question whether their deficits in linguistic priming are specific to language. If patients showed normal color priming, then we could (at the very least) rule out uninteresting explanations for impaired linguistic priming based on factors like fatigue, global slowing, or failure to understand instructions (Goodglass, 1993), and we would learn more about the specificity of the neural damage responsible for aphasia.

Color priming was compared with linguistic priming in the same patients using a grammatical priming task. The existence of grammatical priming is now well established, although its interpretation is still controversial (Jacobsen, 1999). Studies of grammatical gender in Italian (Bates, Devescovi, Hernandez, & Pizzamiglio, 1996), French (Grosjean, Dommergues, Cornu, Guillelmon, & Besson, 1994), German (Jacobsen, 1999), and Russian (Akhutina, Kurgansky, Polinsky, & Bates, 1999) have shown that prenominal modifiers embedded in an auditory phrase or sentence context can prime the nouns they modify. Modifiers matching in grammatical gender can facilitate lexical access (decreasing latencies relative to a neutral baseline) while modifiers with mismatching gender can inhibit, suppress or interfere with lexical access (increasing latencies relative to baseline).

Studies by other investigators have shown that some Italian-speaking patients can identify or judge the gender of a target noun at above-chance levels, even though they are unable to retrieve the phonetic form of the word (Badecker, Miozzo, & Zanuttini, 1995; Devescovi et al., 1997). In the present study, on-line gender priming was investigated in Italian aphasic patients and controls in a task known as gender classification or gender monitoring (Bates et al., 1996; Radeau, Mousty, & Bertelson, 1989), assessing the effect of gender-marked adjectives on patients' ability to classify Italian nouns as masculine or feminine. After the gender-monitoring task, participants were also asked to judge the grammaticality of adjective–noun combinations in an on-line grammaticality judgment task.

PARTICIPANTS

Participants included 21 aphasic patients (native speakers of Italian) with unilateral injuries due to a cerebrovascular accident in the territory of the middle cerebral artery ($>$3 months postonset).[1] All were diagnosed and tested at the same neurological clinic. Eleven were diagnosed with nonfluent aphasia and 10 were diagnosed with fluent aphasia based on a standard aphasia battery for Italian (Ciurli, Marangolo, & Basso, 1996). The 18 males and 3 females had a mean age of 57.5 (range 35–80) and a mean of 12.6 years of formal education (range 4–18). Normal controls (N = 14) were also native speakers of Italian, matched to aphasic patients in age, gender, and education. Participants with red–green color blindness were excluded from the study.

[1] Further details about individual patients can be obtained from the authors at bates@crl.ucsd.edu and pizzamiglio@uniroma1.it.

Materials

Color priming. This task is based on an earlier study of young normals (Marangolo, DiPace, & Pizzamiglio, 1993), which provides further details regarding stimuli and procedures. There were 180 color-priming trials. Primes were circular red, green, or black dots; targets were red or green annular rings that replaced (and surrounded) the space occupied by the primes (shapes and sizes of stimuli were chosen to assure that primes and targets appeared on different parts of the retina). On congruent trials, primes and targets were the same color (red–red, green–green). On incongruent trials, they were in competing colors (red–green, green–red). On neutral trials, primes were an irrelevant color (black). Based on previous work comparing priming across blocks with different ratios of congruent, incongruent, and neutral, we selected a 120 : 30 : 30 ratio (congruent : incongruent : neutral). Subjects were not informed about these probabilities. Stimuli were presented by a PC, which also recorded responses on a two-choice button box. The color of the response buttons matched the color of the targets (green for green, red for red).

Gender monitoring. This study is also based on an earlier study of young normals (Bates et al., 1996), which provides further details on materials and procedure.

A total of 120 adjective–noun phrases were constructed. Targets were 60 nouns with phonologically transparent gender marking (30 masculines ending with *-o* and 30 feminines ending with *-a*) and 60 nouns with phonologically opaque (30 masculines and 30 feminines, both ending with *-e*). Primes were 40 phonologically transparent adjectives ending in *-a* or *-o* (for concordant and discordant conditions) and 10 phonologically opaque adjectives ending in *-e* (for the neutral control condition). All adjectives and nouns started with a consonant and were singular and two to three syllables in length with a mean spoken-word frequency of 40.46 (SD = 54.12, range = 2 to 262; DeMauro, Mancini, Vedovelli, & Voghera, 1993). Stimuli were audio-recorded in carrier phrases and digitized on the Macintosh Sound Edit 16 system. Adjectives were audio-recorded in a rising tone and nouns in a falling tone to insure natural phrasal prosody. Words were spliced from their original carrier phrase and stored in separate registers in the PsyScope Experimental Shell (Cohen, MacWhinney, Flatt, & Provost, 1993). Adjectives were assigned randomly to nouns within a 3 (concordant, discordant, neutral) × 2 (masculine vs feminine noun) × 2 (transparent vs opaque noun) design, which permits a comparison of facilitation (RTs for concordant vs neutral pairs) and inhibition (RTs for discordant vs neutral pairs). Target nouns were never repeated within participants. For phonologically transparent nouns, a sample concordant phrase might be ‘‘GROSSA TORTA’’ (big-feminine cake-feminine) compared with the discordant phrase ‘‘BRUTTO TORTA’’ (ugly-masculine cake-feminine) and the neutral phrase ‘‘GRANDE TORTA’’ (large-ambiguous cake-feminine). For phonologically opaque nouns, a sample concordant phrase might be ‘‘GROSSO PONTE’’ (large-masculine bridge-masculine) compared with the discordant ‘‘BRUTTA PONTE’’ (ugly-feminine bridge-masculine) and the neutral ‘‘GRANDE PONTE’’ (large-ambiguous bridge-masculine).

Grammaticality judgment. The grammaticality judgment task used only 80 adjective–noun pairs, 40 concordant and 40 discordant. Neutral trials with phonologically opaque adjectives (ending in *-e*) were excluded because they are ambiguous for gender in Italian and hence always grammatical.

Procedure

On all tasks, patients and controls were tested individually in a quiet room. The language and nonlanguage tasks were usually given in separate sessions.

Color priming. Participants were asked to indicate the color of the target stimulus as quickly as possible by pressing one of two keys (one for the red target, the other for the green target; left–right counterbalanced over subjects). On each trial, a cross was presented in the center of the screen for 800 ms. After a 100-ms interval, a color prime appeared for 200 ms, followed by a 150-ms ISI. The target then appeared and remained on the screen until the subject pressed the response key, or for a maximum of 5000 ms. Prime–target combinations were presented in a quasirandom order within each block.

Gender monitoring. Participants were asked to indicate the gender of the target noun by pressing one button for Feminine and the other for Masculine (indicated by a gender-marked symbol above each button, left–right counterbalanced across subjects). Latencies were calculated in milliseconds from *target onset* to button-press. There was no pause between the adjective and noun within each word pair. Subjects could respond within a 2000-ms window after *target offset*. The experimenter advanced manually to the next trial, but did not observe or record manually whether the participant had made a correct response.

Grammaticality judgment. All procedures and timing parameters are the same as in gender monitoring, but in this case participants were asked to press one of two buttons indicating whether the adjective–noun pair was grammatical or ungrammatical (indicated above each button by a smiling face and a frowning face, respectively). Button positions for grammatical vs ungrammatical choice were counterbalanced across subjects.

Results

Color priming. Accuracy levels for the color-priming task were close to ceiling for all groups and were not subjected to statistical analysis. Reaction times were first subjected to an omnibus 3 $\times$ 3 analysis of variance, with three between-subject levels of group (nonfluent, fluent, and controls) and three within-subject levels of color priming (congruent, neutral, and incongruent). There were significant main effects of group ($F(2, 32) = 11.76$, $p < .0001$] and color priming [$F(2, 32) = 61.02$, $p < .0001$] and there was a small but significant interaction [$F(2, 32) = 2.63$, $p < .05$]. The main effect of group reflects slower RTs in the two aphasic groups (nonfluent mean = 761.5 ms, $SE = 39.1$; fluent mean = 650.5 ms, $SE = 20.3$; control mean = 493.4 ms, $SE = 14.6$). The main effect of priming reflects faster RTs in the congruent condition (mean = 547.6 ms, $SE = 26.8$) and slower RTs in the incongruent condition (mean = 661.2 ms, $SE = 31.2$), with RTs in the neutral condition only slightly faster than the incongruent condition (mean = 658.8, $SE = 34.1$). Planned comparisons performed on the overall main effect of priming indicate that the facilitative component of color priming was significant [neutral vs congruent, $F(1, 32) = 88.3$, $p < .0001$], but the inhibitory component was not [neutral vs incongruent, $F(1, 32) < 1.00$, n.s.]. Results for each group are illustrated in Fig. 1a (compared with gender priming in Fig. 1b).

Separate analyses within each group showed that overall priming was significant for controls [$F(2, 26) = 16.68$, $p < .0001$], with significant facilitation [congruent vs neutral, $F(1, 13) = 26.32$, $p < .0001$] but no significant inhibition [incongruent vs neutral, $F(1, 13) < 1$, n.s.]. Results were similar for nonfluent aphasics: a large overall priming effect [$F(2, 20) = 12.34$, $p < .0003$], significant facilitation [congruent vs neutral, $F(1, 10) = 21.2$, $p < .0002$], but no significant inhibition [incongruent vs neutral, $F(1, 10) < 1$, n.s.]. In contrast, the analysis for fluent aphasics yielded a large overall effect of priming [$F(2, 18) = 55.4$, $p < .0001$], with significant facilitation [$F(1, 9) = 61.01$, $p < .0001$] and smaller but still significant inhibition [$F(1, 9) = 4.86$, $p < .04$]. However, when a separate ANOVA was performed on the two aphasic groups only, the main effect of priming was still significant [$F(2, 38) = 41.58$, $p < .0001$], but no interaction was found [$F(1, 38) = 1.64$, $p < .21$].

Gender monitoring. One nonfluent patient was excluded from analyses because he failed to respond within the RT window on more than half the trials. Overall accuracy levels were high for elderly controls (96.5%, $SE = 1.0\%$) and low for nonfluent aphasics (73.9%, $SE = 3.2\%$) and fluent aphasics (69.6%, $SE = 2.6\%$). However, individual binomial tests indicated above-chance performance for 7 of the 9 nonfluent patients and 8 of the 10 fluent patients. This means that patients are sensitive to gender class, a critical assumption for the priming experiment.

A 3 $\times$ 3 $\times$ 2 analysis of variance was conducted on reaction times (averaged over correct trials only), with patient group as a between-subjects factor and gender congruency and noun ending as within-subjects factors. There was a significant main effect of patient group [$F(2, 30) = 21.06$, $p < .0001$], reflecting markedly faster RTs for elderly controls (mean = 1294 ms, $SE = 26$) compared with both nonfluent (mean = 1982.8 ms, $SE = 44$) and fluent aphasics (mean = 1835.8 ms, $SE = 43$). There was a significant main effect of gender congruency [$F(2, 60) = 4.35$, $p < .03$], reflecting faster RTs in the congruent condition (mean = 1615 ms, $SE = 53$), slower RTs in the incongruent condition (mean = 1685.8 $SE = 53$), with neutrals

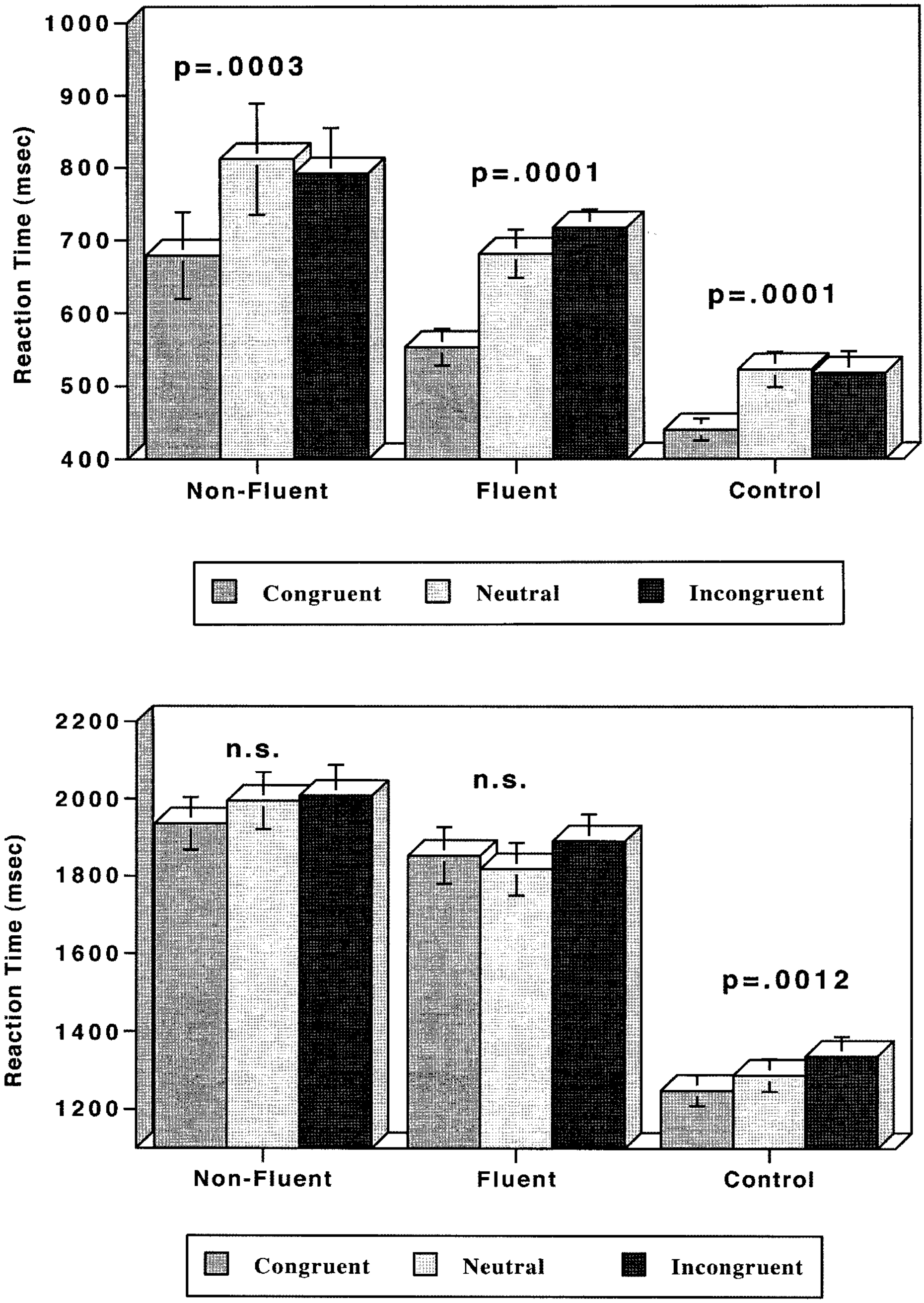

FIGURE 1

falling in between (mean = 1636.3 ms, SE = 51). Planned comparisons indicate no significant gender facilitation [congruent vs neutral, $F(1, 30) < 1.0$ n.s.], but gender inhibition was significant [incongruent vs neutral, $F(1, 30) = 4.25$, $p < .05$], as was the overall priming effect [congruent vs incongruent, $F(1, 30) = 8.16$, $p < .01$]. The main effect of noun ending also reached significance [$F(1, 30) = 23.9$, $p < .0001$], reflecting faster gender-monitoring RTs for transparent nouns (mean = 1589.9 ms, *SE* = 41) than opaque nouns (mean = 1702 ms, *SE* = 44), in line with previous results for young normals. None of the other main effects or interactions reached significance. Results for each group are illustrated in Fig. 1b, for comparison with color priming.

Because the interactions with patient group failed to reach significance, we could conclude that gender-priming profiles are the same for all three patient groups. However, before basing any conclusions on a null result, it was important to determine whether gender priming reached significance within each patient group. The gender congruency effect was significant for the elderly control group [$F(2, 26) = 7.69$, $p = .006$]. However, separate analyses for the nonfluent and the fluent aphasics yielded no main effect of congruency for either group, and hence no evidence for priming. If we look at the priming data for individual patients, asking whether RTs were slower on discordant than concordant trials, we find results in the ''priming direction'' for six nonfluent patients and seven fluent patients. However, these differences were often very small, in line with the nonsignificant priming effects in the parametric analysis. For nonfluent patients, the noun ending effect was significant [$F(1, 8) = 11.25$, $p < .01$], reflecting faster performance on transparent nouns (mean = 1917 ms, *SE* = 63) and slower performance on opaque nouns (mean = 2048.6 ms, *SE* = 61). The interaction did not even approach significance [$F(1, 8) < 1.0$, n.s.]. For fluent patients, the effect of noun ending just missed significance [$F(1, 9) = 3.40$, $p < .10$], though results were in the same direction reported for both groups (transparent nouns, mean = 1780.2 ms, *SE* = 54; opaque nouns, mean = 1891.5 ms, *SE* = 66).

We have shown that these patients are sensitive to gender class (i.e., accurate performance in classifying nouns as masculine or feminine). However, to explain the resounding null result for gender priming in aphasic patients, it would also be useful to know whether they retain sensitivity to gender agreement between the adjective prime and the noun target, since this would be another prerequisite for successful gender priming. This issue is addressed by the grammaticality judgment task.

Grammaticality judgment. The dependent variable for these analyses was ''percentage of items accepted as grammatical.'' If patients have no sensitivity to grammaticality, the congruency effect should be nonsignificant, reflecting a statistically equivalent response bias on all materials. These scores were entered into a $3 \times 2 \times 2$ omnibus analysis of variance, with patient group as a between-subjects factor and congruency and noun ending as within-subjects factors. The analysis yielded no significant main effect of group. There was a robust main effect of congruency [$F(1, 32) = 143.65$, $p < .0001$], which means that correct sentences were accepted more often than incorrect ones. There was also a main effect of noun ending [$F(1, 32) = 6.47$, $p < .02$], and a congruency by ending interaction [$F(2, 32) = 11.89$, $p < .002$], which reflect more failures to detect a gender violation on phonologically opaque nouns. The only other significant effect was a congruency by group interaction [$F(2, 32) = 39.95$, $p < .0001$].

To explore this interaction, separate 2×2 within-subjects analyses were conducted for each aphasic group. For nonfluent patients, congruency reached significance [$F(1, 10) = 5.49$, $p < .05$], which means that they retain above-chance sensitivity to gender-agreement violations (71.1% correct acceptances vs 47.2% incorrect acceptances). The main effect of ending was not significant, but there was a congruency and ending interaction [$F(1, 10) = 5.56$, $p < .04$], reflecting more incorrect acceptances for violations with opaque nouns. For fluent aphasics, congruency also reached significance [$F(1, 9) = 9.26$, $p < .014$]; hence these patients also retain above-chance sensitivity to gender agreement violations (66.2% correct acceptances vs 43.8% incorrect acceptances respectively). The main effect of noun ending missed significance [$F(1, 9) = 4.38$, $p < .07$], as did the congruency by noun–ending interaction [$F(1, 9) = 3.13$, $p < .11$], but they were in the same direction for all groups (i.e., less sensitivity to violations involving opaque nouns).

The noun ending effects raise the possibility that aphasic patients are relying on some kind of ‘‘match the ending’’ strategy rather than gender knowledge, performing above chance only for transparent (‘‘matching’’) items. We therefore carried out post hoc comparisons for each aphasic group, restricted to items that are phonologically opaque. Comparisons between correct and incorrect acceptances did reach significance, for both nonfluent [$F(1, 10) = 43.79$, $p < .0001$] and fluent patients [$F(1, 9) = 5.56$, $p < .05$], which means that their ability to detect violations must be based on abstract knowledge of grammatical gender, independent of overt phonological cues.

SUMMARY AND CONCLUSION

Three conclusions are supported by this study. First, both fluent and nonfluent aphasics displayed robust priming in a color-priming task that does not require linguistic mediation. Second, gender priming did not reach significance in either patient group. Third, despite the absence of gender priming, patients in both groups made above-chance classifications in the gender-monitoring task (indicating sensitivity to the gender status of noun targets, independent of context) and above-chance judgments of grammaticality (indicating sensitivity to gender agreement between the adjective and noun). In other words, these Italian-speaking aphasic patients retain detailed knowledge of grammatical gender, but this knowledge seems to have no effect on real-time lexical access.

Results for color priming eliminate some relatively uninteresting explanations for loss of gender priming in the same patients, including failure to understand instructions, fatigue, difficulty with a button-press, or (as has sometimes been suggested for older patients) fear of computers. This leaves us with two much more interesting possibilities. (1) The absence of linguistic priming may reflect a deficit that is specific to speech and language and (2) impaired linguistic priming may reflect a deficit specific to just those sensorimotor and attentional processes that language shares with other nonlinguistic systems (e.g., speed and grain of auditory processing and recognition of meaningful objects). To distinguish between these options, a systematic series of comparisons is required. First, linguistic and nonlinguistic priming should be compared in tasks that match closely on all procedural dimensions, including proportions of concordant and discordant items, timing parameters, and magnitude of inhibition vs facilitation in normal controls. We did not impose such a match in the present study because we wanted to start with priming tasks that were already established in the literature. Second, our results pertain only to the absence of gender priming. It would be useful to compare linguistic and nonlinguistic priming with a broader array of language tasks, including semantic priming in classic word–word and sentence–word paradigms that have been used extensively in on-line studies of language processing in aphasia. Third, our results were obtained by choosing a nonlinguistic task as far away from language as we could possibly make it (nonsemantic priming in the visual modality) and comparing it with a linguistic task that lies at the heart of language (morphological agreement in the arbitrary domain of grammatical gender). Future comparisons should include a broader array of linguistic and nonlinguistic tasks that overlap on key sensorimotor and semantic dimensions (e.g., auditory priming and visual priming with familiar and meaningful stimuli). Studies to address all three of these points are now underway in our laboratories.

Finally, because these patients retain sensitivity to noun gender and to adjective–noun agreement, disruptions in gender priming are due not to the loss of linguistic knowledge, but to some kind of disruption in the processes by which this knowledge is accessed and deployed in real time. This result underscores the utility of on-line processing techniques for aphasia research.

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