Interactive/Activation in Normal and Brain-damaged Individuals: Can Context Penetrate the Lexical 'Module'?

Arturo Hernandez, Elizabeth Bates, San Diego

Anomia is defined as a pathological deficit in finding and producing words. It is the one symptom that appears in every form of aphasia. It is also an early and ubiquitous symptom in dementia of the Alzheimer's type, and milder forms of anomia are among the most common complaints in normal aging. Classically, anomia has been explained as a disconnection or deterioration in the links between semantic and lexical representations (i.e. between meaning and phonological/orthographic forms – (Farah & Wallace 1992; Gainotti, Silveri, Villa & Miceli 1986; Hadar, Jones & Mate-Kole 1987; le Dorze & Nespoulous 1989; Lucchelli & de Renzi 1992). In fact, some studies have found that training can greatly improve the performance of anomic aphasics, (Colby, Chrisinaz, Parkinson, Graham & Karpf 1981) a clear indication that semantic representations themselves have not been damaged in anomia. Since the residual language deficit in anomic patients seems to revolve around lexical access (i.e. naming), it would be useful to know whether these patients show normal forms of facilitation and/or inhibition in real-time lexical processing. The same is true for the milder word-finding deficits that are often found in normal aging. Is this deficit restricted entirely to word production, or can we find correlates and (perhaps) a possible cause in other aspects of lexical access? And if so, what is the nature of the disturbance in lexical access that underlies this common disorder?

In the present study, we will examine the interaction between discourse and word-level priming in a cross-modal naming paradigm (i.e. pronunciation of visually presented words in an auditory context), in young normal controls, in healthy older adults, and in eight aphasic patients with documented deficits in word finding. We will show that lexical access in context involves a complex, dynamic interplay of facilitative and inhibitory processes. Aphasic patients and older adults display the same qualitative pattern observed in college students, but there is also evidence for increased reliance on context and a reduced ability to overcome or inhibit forms of priming that interfere with the task of word pronunciation – a tendency that is evident in normal aging, and even more prominent in patients with focal brain injury. Before presenting results of this experiment, we will provide a brief overview of the theoretical issues that are at

stake in the study of lexical access in normal populations, followed by an even briefer review of the relevant research on lexical access in aging and aphasia.

1 On Lexical Access in Normal Adults

The nature of lexical-semantic processing is a hotly debated issue in the psycholinguistic literature. On one side stand those who believe that lexical processing is highly modular (Fodor 1983; Forster 1981). In this view, the steps leading from the perception of letters or sounds to the code of the word and the subsequent activation of all core meanings must occur before lexical items can be integrated into a larger sentential or discourse context. In other words, context cannot pre-select lexical items This "autonomy" of lexical processing has received support from a series of studies showing that all meanings of an ambiguous word are immediately accessed regardless of contextual bias (Onifer & Swinney 1981; Seidenberg, Tanenhaus, Leiman & Bienkowski 1982). It is only after a short delay (about 500 ms between prime and target) that the contextually appropriate meaning is accessed. The inference drawn is that associative links along a semantic pathway are activated immediately and that any context effect is post-lexical. The result of these studies have firmly placed the autonomy of lexical processing as a necessary consideration for any theory of on-line lexical-semantic processing.

Despite the strong evidence in favor of the modularity hypothesis, many have opposed this interpretation of reaction time studies with ambigous words. Van Petten and Kutas (Van Petten & Kutas 1987), for example, used event-related potentials (ERP's) to look at the processing of homophones. The authors found that priming (as measured by component of the ERP called the N400) of the semantically inappropriate word began later and was smaller than that of the semantically appropriate word at a short stimulus onset asynchrony (SOA). At long SOAs, only the contextually appropriate meaning was primed. Since all of this occurred before the average time required to register a button press, it is clear why reaction times would not serve to clarify this point. This is not to denigrate reaction time tasks. The present study involves reaction times. The important point to be taken from the Van Petten and Kutas study is that language processing may involve multiple processes that occur well before the collection of reaction times.

The modularity hypothesis also carries a number of additional assumptions regarding the nature of priming effects, with particular emphasis on the contrast between facilitation and inhibition – yet another controversial issue in psycholinguistics. Some authors have proposed that insights into real-time language use must come from the study of language processes that are fast, automatic, and unconscious; methods that elicit slower, controlled and conscious processes are subject to experiment-specific strategies and hence may not generalize to language use outside of the laboratory. For example, some investigators have found that semantic priming effects can be influenced by the subject's expectations about the stimuli, induced by varying the proportion of related/unrelated items and/or the proportion of words to non-words (Neely 1976; Tweedy, Lapinski & Schvaneveldt 1977). Hence, although there is a certain amount of automatic, facilitative

priming that occurs regardless of expectations, some contribution to semantic priming may be due to conscious processes. These conscious processes can cause both inhibition and facilitation. These arguments rest, in turn, on two additional assumptions (following Posner's suggestions for attentional processes outside the verbal domain – Posner & Snyder 1975): all automatic processes are based on facilitation, and the presence of inhibition always implies some form of controlled, strategic processing. Because claims about modularity pertain only to automatic processes, it follows that studies investigating the autonomy hypothesis should avoid methods that induce inhibitory processing.

However, other theorists have argued against the traditional automatic/controlled processing distinction. In an interactive/activation framework, for example, both inhibition and facilitation are thought to occur early in processing (Colombo 1986; Grainger 1990; McClelland & Rumelhart 1981). In fact, evidence for very rapid and automatic forms of inhibition have been reported in non-verbal priming studies (Marangolo, Dipace, & Pizzamiglio 1993). In the same vein, it could be argued that well-known phenomena like the Stroop effect provide evidence for fast, automatic forms of inhibition in the language domain. Thus there is good reason to believe that both facilitation and inhibition can occur early in language processing. If this view is correct, then we need not assume that expectations always lead to slow, strategic and experiment-specific forms of processing; rather, expectations could be used to set up rapid and relatively unconscious patterns of inhibition and facilitation that do generalize to language performance outside of the laboratory.

Investigators have studied facilitation and inhibition (and automatic and controlled processes) by manipulating subject expectancies or SOA's with normal controls, and/or by looking at populations in which there is some reason to believe that these processes are differentially impaired. The relevant populations have included individuals with diffuse or focal brain damage (i.e. Alzheimer's patients or aphasics) as well as normal geriatric populations. In the following section, we will review some of the literature on the effects of aging and neurological insult on 'real-time' language processing, with a particular focus on the relative contribution of facilitation and inhibition.

2 Language Processing in Older Adults and Brain-Damaged Individuals

Recent studies have revealed a number of differences between older adults and younger college controls. These include impairments in short-term and long-term memory (Mitrushina & Satz 1991; Salthouse 1991) which can affect both the ability to remember detailed information of previous discourse or interpret sentences correctly (Hasher & Zacks 1988; Light & Burke 1988; Salthouse 1991). Age-related changes have been attributed to efficiency of processing brought about by a general cognitive slowing (Nebes & Brady 1992; Salthouse 1991), a decline in processing capacity or attentional resources (Hasher & Zacks 1988), or the inability to inhibit irrelevant information, a special case of the reduced capacity theory (Hasher, Stoltzfus, Zacks & Rypma 1991; Hasher & Zacks 1988). These theories imply that a more general processing

change (i.e. limited short-term memory) is responsible for impairment in more specific domains of cognitive processing (Salthouse 1991).

Within this framework, the older adult population can provide an important test case for the theories of lexical processing described above. Presumably, changes in general processing should have no effect on automatic semantic priming, since automatic processes (like reflexes – Fodor 1983) are not affected by general processing demands. Therefore a change in general processing capacity should only influence post-lexical processes. Studies with older adults have revealed that automatic semantic priming remains unchanged in older adults (Chiarello, Church & Hoyer 1985) and adults with Alzheimer's disease (Ober, Shenaut, Jagust & Stillman 1991). In addition, syntactic processes which are thought to be even less subject to strategies (i.e. more automatic) have shown little or no decrement with aging when memory load is controlled (Zurif, Swinney, Prather, Wingfield & Brownell 1993). Within this view, effects of aging should only be observed on syntactic processes that involve long-distance relationships (i.e. processes that require the listener to hold several elements in memory). Taken together, these studies support a view in which automatic processes are not affected by changes due to aging or diffuse neurological damage.

In aphasia, a much more localized and focal type of brain damage, differential impairment of automatic and controlled processing has been proposed. Specifically, it has been argued that Broca's aphasics fail to show automatic semantic priming, but can use a set of heuristic (i.e. conscious) processes. By contrast, Wernicke's aphasics show no decline in automatic priming but fail to employ heuristic strategies (Milberg, Blumstein, Katz & Gershberg 1993). This is an interesting proposal that could account, in principle, for many of the double dissociations that are observed between Broca's and Wernicke's aphasia (Bates, Wulfeck & MacWhinney 1991). However, other studies have shown that Broca's aphasics do show evidence for forms of semantic and syntactic priming that are usually assumed to reflect automatic processing (Hagoort 1993; Ostrin & Tyler 1993). As an alternative to the automatic/controlled dichotomy, it has been argued that Broca's aphasia represents a general slowing of activation for linguistic information, with serious and rather specific consequences for the coordination of parsing operations and/or for efficient integration of lexical items into contextual frames (Friederici & Frazier 1992; Friederici & Kilborn 1989; Kolk & Van Grunsven 1985; Ostrin & Tyler 1993).

In contrast with the growing literature on lexical processing in Broca's and Wernicke's aphasics, there are surprisingly few 'on-line' studies of lexical access in patients who suffer from milder forms of language impairment due to a focal lesion. In many cases, these patients have evolved from a more severe fluent or non-fluent aphasia in the first few months after their injury, to a milder form of aphasia restricted primarily to word finding deficits (i.e. anomia). Because these patients themselves often represent a developmental continuum from more serious forms of aphasia, it is reasonable to ask whether their word-finding deficits reflect a milder variant of the deficits in "on-line" lexical access reported for Broca's and/or Wernicke's aphasia. And the continuum may extend in the other direction to include healthy older adults.

In the present study, a cross-modal naming paradigm was used to study lexical access in college-aged adults, older adults, and a group of higher-level aphasic patients (i.e.

anomic aphasics). We have departed from other real-time studies of lexical processing, in two respects. First, most studies with impaired and normal populations have used lexical decision, which may be susceptible to post-lexical search strategies (Balota & Lorch 1986) and is less naturalistic than other tasks such as naming. In order to avoid some of these problems, the current study used cross-modal naming (i.e. time required to pronounce a visual word in an auditory context). Naming is thought to provide a deeper and less strategic measure of lexical access; whether or not this is the case, it is certainly true that cross-modal naming produces faster latencies than lexical decision. Second, most studies have used minimal semantic contexts, i.e. word pairs or a brief sentence. Instead, we will assess priming in a discourse context. The use of discourse-level priming should help to provide subjects with robust semantic expectations, while insuring a more naturalistic mode of language processing (Foss 1982).

In the procedure adopted here, visual word pairs (a prime followed by a target) are embedded in an auditory context that is several sentences long. The word pairs may be semantically related to each other or not (W+ vs. W–). The target may or may not be a good completion of the discourse context up to that point (C+ vs. C–). Finally, a neutral control condition will be used in which subjects will see an unrelated pair in which neither word is a good completion of the context. We will assume that reaction times which are significantly faster than this neutral control reflect some form of facilitation (from the context and/or the prime word), while reaction times that are significantly slower than this neutral control reflect some form of inhibition. An example of these items can be seen in Table 1.

In essence, we are placing discourse-level priming in competition with word-level priming. To ensure this competition, the word pairs will be presented at a 200 ms stimulus onset asynchrony (SOA), an interval at which there should be little or no contextual penetration according to a purely modular lexical-semantic account. If the modular account is correct, we may find a main effect of word-level priming (an automatic form of activation) and a main effect of contextual priming (a post-lexical effect), but no interaction. Above all, contextual effects should not eliminate or reduce word-level effects in the rapid stimulus-response windows adopted in the present study.

The second point of this study is to investigate how contextual integration and lexical-access are affected by aging. Previous results have offered a number of possibilities with regard to the effects of aging on language processing. Some theories imply large changes in language processing with age (Hasher & Zacks 1988) while others find little or no change in language processing with age (Ober et al. 1991; Zurif, Swinney, Prather,

Table 1 Sample conditons from the experiment

"The boy was driving the car down the"	
ROAD-STREET (W+/C+)	APPLE-STREET (W–/C+)
APPLE-ORANGE (W+/C–)	STREET-APPLE (W–/C–)
Neutral Control = APPLE-KNOB	

Wingfield & Brownell 1992). The present experiment should help to disambiguate these positions by observing the way in which two robust phenomena (local word-level semantic priming and global discourse-level priming) when placed into competition are affected by aging. If the failure-of-inhibition account of cognitive impairments in aging is correct, then it should be particularly difficult for older adults to suppress discourse-level or word-level effects that slow word naming in the young; at the same time, we may expect a sparing and (indeed) an augmentation of the facilitative context effects that are observed in younger subjects.

Finally, we hope to shed some light on the nature of the underlying processes that characterize the naming deficit shared by anomic patients. If anomic patients display quantitative or qualitative changes in the normal patterns of lexical facilitation, inhibition and competition observed within this paradigm, then we may infer that these processes play some role in naming disorders. On the other hand, if these patients show the same patterns of word- and discourse-level priming displayed by age-matched normal controls, we must conclude that the locus of their naming deficit lies elsewhere.

3 Method

Subjects

Sixty-two subjects were tested using the cross-modal word pair paradigm. The young controls were twenty undergraduates at the University of California, San Diego, recruited through the subject pool of the Department of Psychology. The older adult group was made up of fifteen right handed individuals between the ages of 63 and 85 (mean = 68.6429, sd = 10.2553).

The aphasics comprised of eight subjects with slight to moderate word-finding difficulties. These were mainly recruited from the San Diego Veterans Administration Hospital but also from surrounding hospitals. The patients all were between the ages of 39 and 79 (mean = 65.54, sd = 10.48) and all had suffered a single stroke to the left hemisphere. All Eight patients were classified as anomic aphasics. Classification of aphasia type was based on subjects' performance on the Western Aphasia Battery (WAB). Patients were all at least six months post stroke onset (mean = 5, sd = 3.66), had no history of alcohol or drug abuse, no history of psychiatric illness, no other significant brain disorder or dysfunction, normal visual acuity, normal hearing acuity, minimal limb apraxia, minimal motor speech involvement. A summary of patient information can be seen in Table 2.

Table 2 Aphasic Patient information

ID #	Age	Sex	Handedness	Etiology	WAB Classification	WAB AQ (naming)	Lesion
JS084	68	M	R	CVA	A-mild	97.5 r (8.8)	Frontal Parietal
HP139	75	M	R	CVA	A	94.4 r (9.3)	Left Frontal-Parietal
TB247	65	M	R	CVA	C/A	73.0 r (8.9)	N/A
BU252	79	M	R	CVA	A	84.3 r (8.3)	N/A
PB405	67	M	R	CVA	Trace A	98.0 r (10)	Anterior
ES406	71	M	R	CVA	A	85.6 r (7.5)	N/A
JW410	65	M	R	CVA	A	85.5 r (8.6)	N/A
MC421	66	M	R	CVA	A	83.2 r (8.1)	N/A

A = Anomic, W = Wernicke, B = Broca, C = Conduction

Apparatus

Subjects were run on a Macintosh IIsi computer connected to a Carnegie-Mellon button box. The experimental trials were administered using the *PsyScope* experimental shell developed at Carnegie-Mellon University by Brian MacWhinney and Jonathan Cohen (Cohen, MacWhinney, Flatt & Provost 1993). All of the experimental materials were placed on a Syquest removable cartridge drive.

Test Materials and Design

The materials in this task consisted of fifteen texts chosen from third-grade-level textbooks. All texts were 7-8 sentences long. The passages were chosen to address a number of culturally neutral topics (i.e. animals, space, firefighters, etc.). Between six and eight words were extracted from every text (approximately one per sentence). The words that were extracted from the texts (all common nouns) were replaced with a word pair (also common nouns). The word pairs were placed in one of five conditions and coded according to the relationship of the target to the text (context+ or context–) and to itself (word+ or word–). In the first condition, both prime and target were good completions of the discourse up to that point (W+/C+). In the second condition, the prime was a bad completion but the target was a good completion (W–/C+). In the third condition, the prime and target were both bad completions but were related to each other (W+/C–). In the fourth condition, the prime and target were unrelated

semantically to each other, but the prime was a good completion (W–/C–). Finally, the neutral control consisted of word pairs that were neither related to themselves nor to the context (neu). There were 20 items per condition. Congruent words were all the original words in the text. Incongruent words were chosen so as to not match the text. When a second congruent word was needed, a synonym of the completion which was close in frequency was chosen. The incongruent word pairs were chosen to be strongly associated. Conditions were randomly assigned across the experiment. Every subject received the same random order.

The word targets were all balanced for frequency of occurrence using the Kucera and Francis norms (1982). In addition, they were balanced for length. Although the stimuli where not randomized across subjects (one cannot randomize sentences in a discourse paradigm), the conditions that appeared were randomized so that subjects could not predict which of the five conditions would appear next.

The baseline condition consisted of 30 word pairs (fifteen related and fifteen unrelated). These were presented in the same order to each subject, but like the experiment these conditions were randomized. The baseline was used primarily as a way to provide subjects practice with perceiving and reading word pairs in isolation before the more difficult task of seeing similar items in context. Therefore, we will not present analyses of priming data for these out-of-context pairs.

Procedure

All of the undergraduate students were tested in Experimental rooms located at the Center for Research in Language at the University of California, San Diego campus. Both older adults and Aphasic patients were tested at the VA San Diego.

Each session consisted of two parts. In the baseline section, subjects were instructed that two words would appear one after the other and that they should pronounce the second word into the microphone as quickly as possible. The word pair was presented at a 200 msec SOA. After the baseline section, the participants were told that they would be hearing a set of texts in which they had to answer a multiple-choice question. Thus they should pay attention to the content of the passage. In addition, they were also advised that during the text the recording would stop and two words would appear on the screen. Subjects were told that they should pronounce words as quickly and accurately as possible. They were informed that the words might or might not fit with the text. The texts were presented auditorally. At a predetermined point during the text the sound would stop and a visual word was immediately presented on a computer screen for 200 ms followed by a target word. College normals were given a response window of 1 second while older adults and aphasics were given two seconds to respond. If he/she responded before the elapsed time had passed, then the text continued. If the subject did not respond within the response window, a no response was recorded, the word would come off the screen and the auditory text would resume. At the end of the text a question would appear on the screen. These questions asked about the text that had just been presented, and served as a rough measure of the level of comprehension. Once the question was answered the next passage would begin.

Table 3 Mean Reaction Times in ms and percentage of errors for each group

	Context +	Neutral	Context–	Facilitation	Inhibition
Young Adults					
Word+	530 (0.29 %)	537 (0.29 %)	536 (1.17 %)	6.95	–1
Word–	509 (0.58 %)	537 (0.29 %)	549 (0.58 %)	27**	12*
Older Adults					
Word+	668 (0 %)	669 (1.33 %)	661 (3 %)	1	–8
Word–	620 (0.33 %)	669 (1.33 %)	697 (0.33 %)	48**	27*
Aphasics					
Word+	922 (1.33 %)	989 (1.17 %)	963 (1.17 %)	67*	–26
Word–	868 (0.83 %)	989 (1.6 %)	1005 (1.5 %)	121**	16

* $p < 0.05$, ** $p < 0.01$

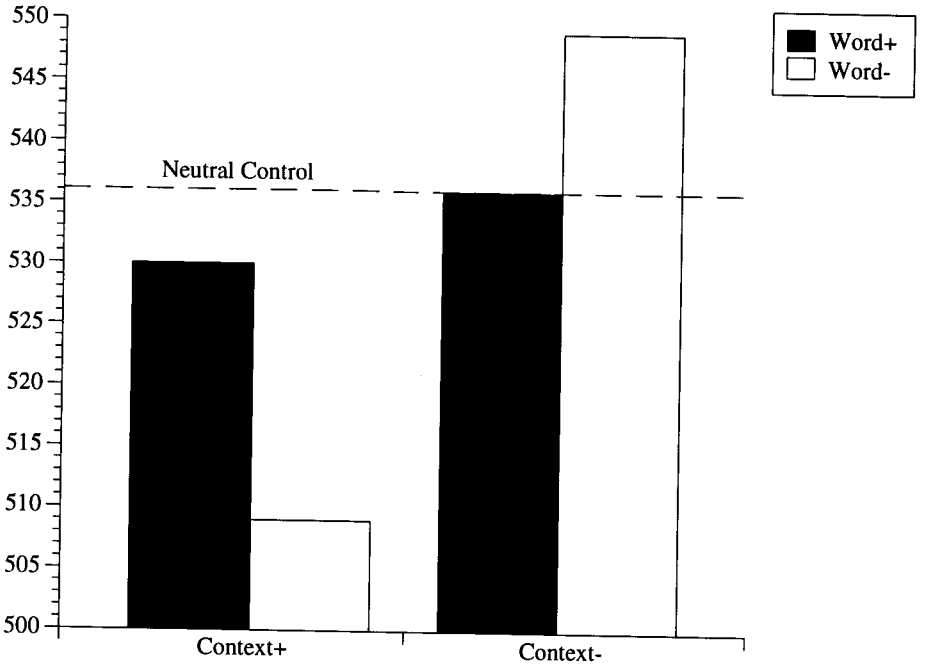
4 Results and Discussion

College Controls

Experimental reaction times: The raw data for normal controls can be seen in Table 1. The raw reaction times were placed into a 2 (word relationship) x 2 (context relationship) within-subjects ANOVA. There were main effects of word relationship, $F(1,19) = 4.949$, $p < 0.038$, contextual relationship of the target word, $F(1,19) = 35.49$, $p < 0.000$, and a word relationship by contextual relationship interaction, $F(1,19) = 25.83$, $p < 0.000$. The contextual relationship was significant over items, $F(1,76) = 7.04$, $p < 0.01$, and the word relationship by contextual relationship interaction was marginally significant over items, $F(1,76) = 3.19$, $p < 0.078$. The results showed that W+ words were read in 533 ms while W– words were read in 529 ms. Furthermore, C+ words were read in 519 ms while C– words were read in 542 ms The word relationship by contextual relationship interaction revealed that for W+ words contextual relevance was unimportant (530 vs. 536 ms). For W– words contextual relevance was very important (509 ms vs. 549 ms). In addition, notice that W–/C+ words are read faster than W+/C+ words (509 vs. 530 ms).

A set of t-tests was run in order to compare across conditions and to compare each condition to the neutral control. These confirmed the findings in the general ANOVA. First of all, for W– words the C+ condition was faster than the C– condition, $t(19) = 7.978$, $p < 0.000$. In addition, it was found that W+/C+ condition was significantly slower than the W–/C+ condition, $t(19) = 5.32$, $p < 0.000$. In addition, comparisons with the neutral control revealed that the W–/C+ condition was significantly faster than baseline, $t(19) = 5.96$, $p < 0.000$, and that the W–/C– condition was significantly slower than baseline $t(19) = 2.39$, $p < 0.02$.

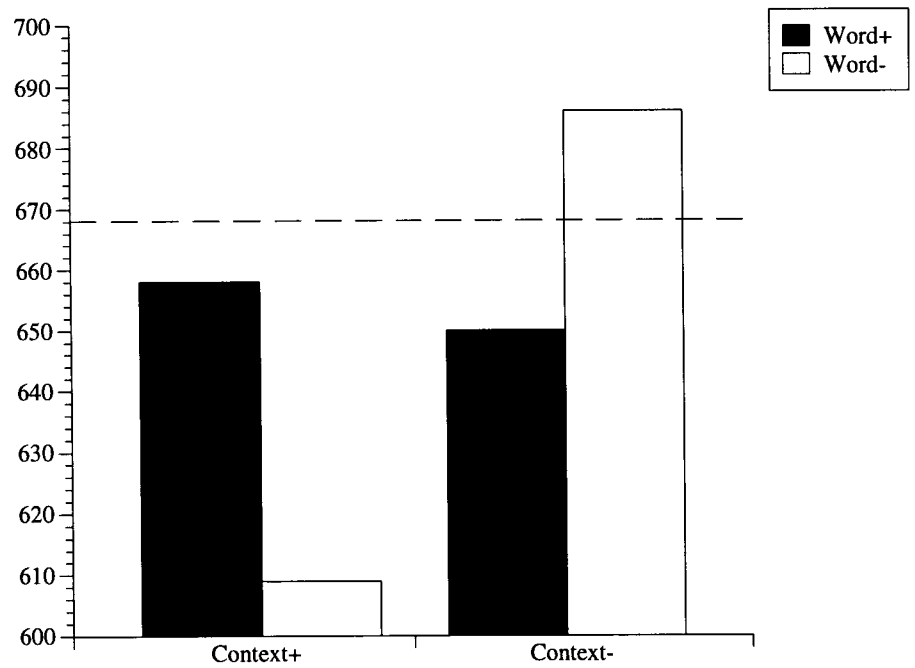
Figure 1 Word relationship by contextual relationship interaction for college controls



To simplify analyses across groups, the mean RT for neutral control items for each subject was subtracted from each reaction time for that subject in the four experimental conditions. These adjusted reaction times for the college controls were placed into a 2 (word relationship) x 2 (context relationship) within-subjects anova. This yielded a significant main effect of word relationship, $F(1,19) = 4.949$, $p < 0.038$, contextual relationship of the target word, $F(1,19) = 35.49$, $p < 0.000$, and a word relationship by contextual relationship interaction, $F(1,19) = 25.83$, $p < 0.000$. The contextual relationship was significant over items $F(1,76) = 7.14$, $p < 0.009$, and the word relationship by contextual relationship interaction was marginally significant over items, $F(1,76) = 3.32$, $p < 0.072$. These results revealed that the W+ words were read only 3 ms faster than baseline while W– words were read only 7 ms faster than baseline When the target was a good completion (C+) it was read 17 ms faster than neutral, and 5 ms slower than neutral when it was not (C–). In addition, the WxC interaction revealed that the difference between C+ and C– words was larger for W– words (–27 ms vs. +12 ms) than for W+ words (–6 ms vs. 0 ms). It also was clear that the W–/C+ words were read about 21 ms faster than W+/C+ words.

The results from the college controls seem very clear. The data do not support a purely modular model in which word-level and discourse-level priming cannot interact, and they also show that discourse effects can operate very early. However, it is clear that there are constraints on the nature of the interaction between context and word primes. First, there is a significant amount of facilitation (i.e. RTs faster than baseline) when

Figure 2 Word relationship by contextual relationship interaction for older adult controls



the target is contextually relevant and the prime is not (W–/C+), and a significant amount of inhibition (i.e. RTs slower than baseline) when the prime is contextually relevant and the target is not (W–/C–). Hence there do appear to be early and rapid forms of contextual facilitation and inhibition. However, W+ words are neither facilitated nor inhibited relative to the neutral control. Thus, at least for normal controls, words which are locally semantically related (W+) are apparently unaffected by context. The apparent "encapsulation" of local semantic priming from context appears to provide evidence in favor of a modular view. However, this view is hard to maintain when the W+ and W– conditions are compared within and across discourse conditions. If local semantic priming were truly modular, then W+ items should be faster than W– items regardless of contextual constraints. This was clearly not the case. In fact, W+/C+ words were actually significantly *slower* than W–/C+ words. In other words, the usual "automatic" effect of priming at the local level has been thwarted and even reversed by context; or, conversely, the usual facilitative effect of context has been thwarted or suppressed by a local relationship.

Further evidence in favor of an interactive account comes from the various C– conditions. First, there was no difference in reaction times between neutral control items (unrelated words that are both unrelated to the context) and the W+/C– condition (related words that are both unrelated to the context). Hence it does look as though the expected "local" effects of word-word priming have been blunted when neither of these words fit the discourse context, suggesting that context can exert some kind of

inhibitory effect on "automatic" local priming. Second, the slowest reaction times across all experimental and control conditions were observed for unrelated word pairs in which the prime fits the context but the target does not (W–/C–). The significant difference between W–/C– items and the neutral control also suggests that context has some kind of competitive or inhibitory effect.

We propose that the interactions between discourse-level and word-level priming observed in this study reflect a competition between the two items in a word pair for the role of "best completion" at the discourse level, as follows.

In the W–/C+ condition, the first word (i.e. the word prime) is a bad completion of the context. In a model that permits contextual pre-selection, we could argue that the first word has not been facilitated by context, and may indeed have been actively suppressed. In a model that has "bottom-up priority" with no pre-selection, we would have to argue (at best) that the first word receives no post-access boost (i.e. there is no effort to integrate it into the context). Indeed, there may be active efforts to inhibit incongruent primes as soon as they are recognized. In either case, these incongruent primes are so weak that they cannot provide much activation *or* inhibition for the target word that follows. Thus subjects quickly pronounce the second word, which is a good completion that can be integrated easily into the context.

By contrast, in the W+/C+ condition, the first word (the prime) is an excellent completion of the context. In a model that permits contextual pre-selection, we could argue that the first word is recognized early because its threshold was lowered by spreading activation. In a model that precludes contextual pre-selection, we would have to argue that these congruent primes receive a very rapid post-access boost, with rapid integration into the context. When the second word (the target) appears, it is at a considerable disadvantage, for two reasons. First, there is a slight delay because the first word is still being integrated into the context (where it fits so well). (This delay would presumably hold whether the target word fits the context or not.) Second, because the target and the prime are both good completions of the sentence, they are strong competitors – and this competition takes some time to resolve. In a sense, the second (target) word is like a rightful heir that has been (temporarily) supplanted by an impostor.

A similar logic can be used to explain why W–/C– items are significantly slower than neutral controls. In both these conditions, there is no "local" semantic relationship between prime and target, and in both cases the target is not a good completion at the discourse level. However, in the W–/C– condition (but not in neutral controls), the prime word *is* a good completion. In a model that permits pre-selection, we could argue that the prime was already activated by the context before it could be recognized. In a model that precludes pre-selection, we would have to argue that the first word in the pair received a post-access boost, and that efforts began to integrate it into the context. However, in the task that we have imposed upon our subjects, they are required to read the second word. That word has little chance in a competition for "best completion", because it is semantically incongruent and because the congruent prime has already made it in the door. Therefore the target word receives inhibition from the context, and from its competitor. This is the worst possible circumstance for word recognition, a fact that shows up in the exceptionally slow reaction times for W–/C– items.

Finally, consider the finding that word-level priming fails to occur when neither word fits the context (i.e. W+/C–/is not faster than the neutral control). Why has this supposedly automatic local priming failed? We suggest that this phenomenon can be explained if we assume that discourse context exerts an early and powerful inhibitory influence on words that are bad completions. Because the prime is a bad completion in both these cases, it is quickly suppressed (whether this occurs before or after lexical access is irrelevant to this point). As a result, the prime is so weak that it cannot exert a facilitative effect on the target word that follows, and hence no local priming occurs. As we have pointed out, these effects can be explained with or without invoking preselection. However, at the very least, it is clear that discourse effects are very strong, very fast, and inhibitory in nature (Marslen-Wilson & Tyler 1987). It would be easier to explain how such powerful effects get off the ground within a 200-ms window if we were able to assume some form of pre-selection. Such pre-selection may come from the discourse level, or it may represent a build-up of lexical activation from the related words that invariably occur in a long discourse passage. If the latter is true, then we might expect rapid facilitative and inhibitory effects of this kind following scrambled prose or random word lists. Other studies using lists of lexically related but syntactically unrelated words have failed to find such strong priming effects (Kilborn 1987), but to our knowledge, none of these have used the cross-modal naming paradigm. Hence the nature of the context effects observed in the present study is still open to debate. For present purposes, we can conclude that discourse does have inhibitory and facilitative effects on lexical access, and these effects fall within the time window that is usually reserved for automatic processes. This brings us to the next part of our study, where the paradigm is extended to elderly controls and aphasic patients.

Older Adult Controls

Experimental reaction times: The raw reaction times for the older adult controls were placed into a 2 (word relationship) x 2 (context relationship) within-subjects anova This yielded a significant main effect of contextual relationship of the target word, $F(1,14) = 10.38$, $p < 0.006$, and a word relationship by contextual relationship interaction, $F(1,14) = 24.62$, $p < 0.000$, but (in contrast to our findings for young normals) no main effect of word relationship. The main effect of contextual relationship, $F(1,76) = 7.26$, $p < 0.009$, and contextual relationship by word relationship interaction, $F(1,76) = 5.16$, $p < 0.026$ were also significant across items The target was read in 683 ms when it was a good completion (C+), and 736 ms when it was not (C–). In addition, the WxC interaction revealed that for W– words, the difference between C+ and C– condition was large, (658 ms vs. 759 ms). For W+ words, both the C+ words and C– condition elicited equal reaction times (706 ms vs. 714 ms). In short, subjects showed contextual priming for unrelated words but not for related words. In addition, like normal young controls, older adult controls read W–/C+ words faster than W+/C+ words (658 ms vs. 706 ms).

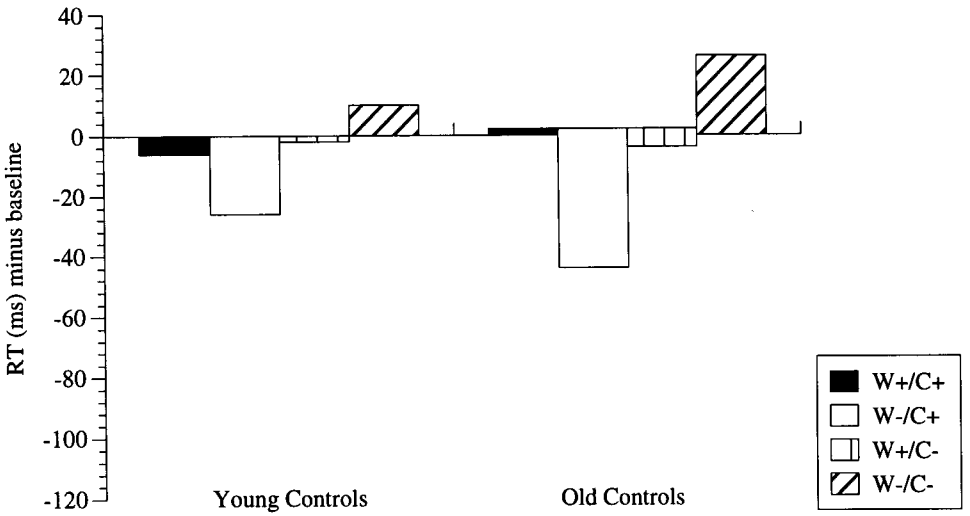
A set of t-tests were conducted on the raw reaction times in order to compare across conditions, and to compare each condition to the neutral control. Comparisons with

the neutral control revealed that the W–/C+ condition was significantly faster than baseline, $t(14) = 4.09$, $p < 0.001$, and that the W–/C– condition was marginally slower than baseline $t(14) = 2.07$, $p < 0.057$. Further analyses revealed that the W+/C+ condition was significantly slower than the W–/C+ condition, $t(19) = 4.58$ $p < 0.000$.

Adjusted reaction times: Once again a set of analyses was conducted on reaction times with the neutral control subtracted out. The adjusted reaction times for the older adult controls were placed into a 2 (word relationship) x 2 (context relationship) between-subjects anova. This yielded a significant main effect of contextual relationship of the target word, $F(1,14) = 10.58$, $p < 0.006$, and a word relationship by contextual relationship interaction, $F(1,19) = 24.73$, $p < 0.000$. Furthermore, both effects were also significant across items, $F(1,76) = 8.65$, $p < 0.004$, and $F(1,76) = 6.26$, $p < 0.014$. These analyses mirrored the raw reaction time analyses. The target was read 25 ms faster than baseline when it was a good completion (C+), and 9 ms slower than baseline, when it was not (C–). In addition, the WxC interaction revealed that for W– words, the C+ condition was 48 ms faster than baseline and the C– condition was 27 ms slower than baseline. For W+ words, both the C+ words and C– condition were slightly faster than baseline (1 ms and 8 ms respectively). In short, subjects showed contextual priming for unrelated words but not for related words. In addition, like normal young controls, older adult controls read W–/C+ words faster than W+/C+ words.
The results from elderly controls reveal essentially the same qualitative pattern of data that was present in the young controls. To investigate any quantitative differences that may exist between groups, an ANOVA was run with both groups included.

Comparisons between younger and older adult controls: The adjusted rt data was placed into a 2 (group) x 2 (word relationship) x 2 (context relationship) mixed design ANOVA with group as the only between subjects factor. The ANOVA yielded a main effect of context relationship, $F(1,33) = 30.63$, $p < 0.000$, a word relationship by contextual relationship interaction, $F(1,32) = 45.75$, $p < 0.000$, and a group by word relationship by contextual relationship interaction, $F(1,32) = 9.73$, $p < 0.004$. The word relationship by context relationship interaction revealed the same pattern that was seen in each separate group analysis. Namely, subjects were faster than baseline when the target word was contextually related than when it was not. Furthermore, subjects showed contextual priming effects only when there was no local word relationship. The three-way interaction revealed that older adults showed a considerable amount of increased facilitation in the W–/C+ condition (48 vs. 27 ms), increased inhibition in the W–/C– condition (27 vs. 12 ms). In addition, there was a slight reversal in the W+ conditions. W+/C+ were equally facilitated for both groups but W+/C– words were more facilitated for older adult controls than for younger controls. The three-way interaction therefore arises from a considerable increase in the size of effects for W– words, and a slight reversal in the W+ conditions for elderly controls relative to young controls.
To summarize, so far. Normal aging does seem to have small effects on the nature of both local and global facilitation and inhibition in the present experiment. First of all, aging seems to increase both facilitation and inhibition when there is no local word relationship. Second, the rapid form of inhibition between both words seems to increase slightly (21 ms vs 48 ms). Once again it is difficult to understand how elderly subjects

Figure 3 Word relationship by contextual relationship by group interaction for old and young controls



could be more facilitated for two words that are unrelated. Thus it appears that elderly controls are attempting to integrate the first word and that there is an inability to 'let go' or inhibit the activation of the second word as quickly. Thus the second word is pronounced even slower. This raises an interesting possibility. Is the increased inhibition between good sentence completions caused by a breakdown in the ability to inhibit the first word? This does seem to be confirmed by the fact that elderly controls show more inhibition in the W–/C– condition. That is, older adult controls are less able to suppress the integration of a good completion when it is followed by a bad completion. Thus it becomes even clearer that inhibition and facilitation relative to baseline may be a product of many overlapping effects which are occurring before reaction times are collected.

To better understand the nature of these multiple effects, a group of high-level aphasics were run on the same task. In using a more impaired group of subjects, it may become clearer which forms of suppression and excitation are affected by a decrease in language processing capability.

Aphasic Individuals

Eleven subjects were run on the experiment. Three were dropped because of high error rates and a high number of no responses. For these reasons all analyses involved only eight subjects.

Experimental reaction times: The raw RT's were placed into a 2 (word relatedness) x 2 (context relatedness) within-subjects anova. The results yielded a significant effect of

context relatedness, $F(1,7) = 6.36$, $p < 0.040$ and a significant word relationship by context relationship interaction, $F(1,7) = 7.13$, $p < 0.032$. The main effect of context relationship was significant over items, $F(1,76) = 10.63$, $p < 0.002$ while the context relationship by word relationship interaction was marginally significant, $F(1,76) = 3.775$, $p < 0.056$. In addition, a set of t-tests was conducted in the same fashion as had been done with both control groups. The t-tests showed that the W–/C+ condition, $t(8) = 5.87$, $p < 0.0002$ and the W+/C+ condition were faster than baseline. In addition, it was found that the W–/C+ condition was marginally faster than the W+/C+ condition, $t(10) = 1.86$, $p < 0.09$. Although the data are considerably noisier (and reaction times are very large, mean = 964) aphasics show the same general pattern presented by both control groups. Namely,

W–/C+ < W+/C+ < W+/C– < W–/C–

Adjusted reaction times in context: The adjusted RT's were placed into a 2 (word relatedness) x 2 (context relatedness) within-subjects anova. The results yielded a significant effect of context relatedness, $F(1,7) = 6.37$, $p < 0.04$ and a significant word relationship by context relationship interaction, $F(1,7) = 7.13$, $p < 0.032$. Both the main effect of context relationship, $F(1,76) = 14.52$, $p < 0.000$, and the word relationship by context relationship interaction, $F(1,76) = 5.37$, $p < 0.023$. This showed the same general pattern which was seen in the raw reaction time data and of both control groups. Despite the fact that the ordering of the results are essentially the same, it is important to note that Aphasics as a group appear to be showing more facilitation. This is especially true for words which are contextually related. Note, however, that W+/C– words are showing the beginnings of facilitation. The results suggest that while the ordering of conditions relative to themselves is maintained, there is a change in the magnitude of effects when compared to Older adults and young adults. To further evaluate this a set of analyses was run with group as a variable.

Comparisons between older adults and aphasics: The adjusted reaction times for both groups were put into a 2 (group) x 2 (context relationship) x 2 (word relationship) ANOVA with group as the only between subjects factor. The analyses yielded a main effect of group, $F(1,21) = 6.32$, $p < 0.02$, contextual relationship, $F(1,39) = 14.79$, $p < 0.001$, an interaction of word relationship by contextual relationship, $F(1,39) = 34.31$, $p < 0.000$, and a marginally significant group by contextual relationship interaction, $F(1,39) = 3.73$, $p < 0.033$. The results reveal that aphasic patients show a larger amount of facilitation relative to baseline, especially for target words which are contextually relevant. In fact, Aphasic patients show a 94-msec facilitation for C+ words whereas older adults show a 24-msec facilitation effect for those same words. Finally, it appears that W+/C– words are slightly facilitated for Aphasic patients but only at baseline for the other two groups. Clearly, the Aphasic patients, while preserving the same general pattern, are being facilitated by any condition in which there is either a local word relationship or a global contextual relationship. Thus the locus of their deficit appears to lie not in the absence of local or global forms of priming, but in the ability to coordinate and integrate these sources of information in an efficient manner.

Figure 4 Word relationship by contextual relationship interaction for aphasics

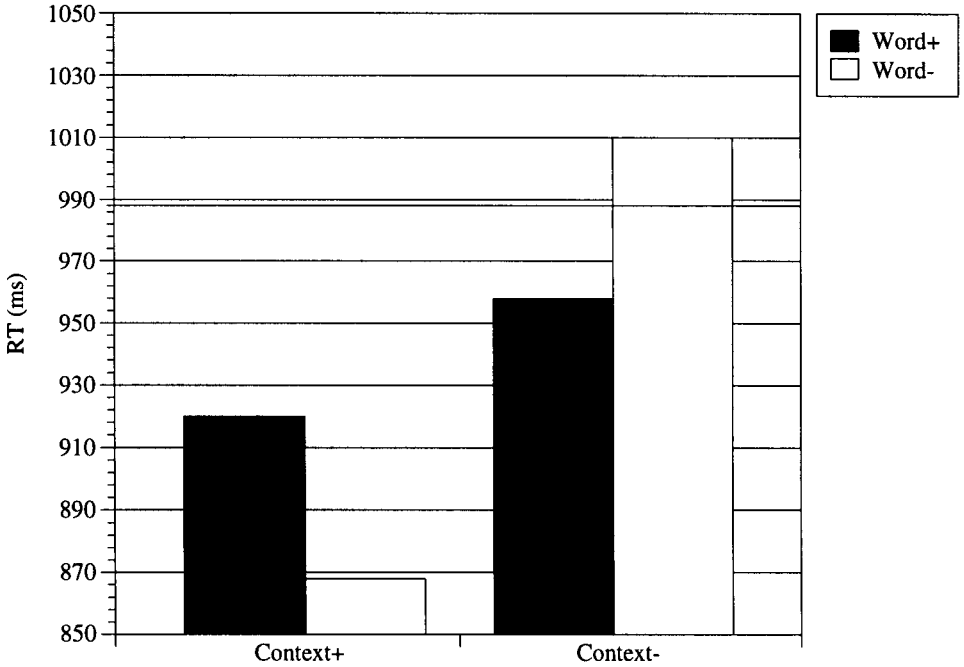
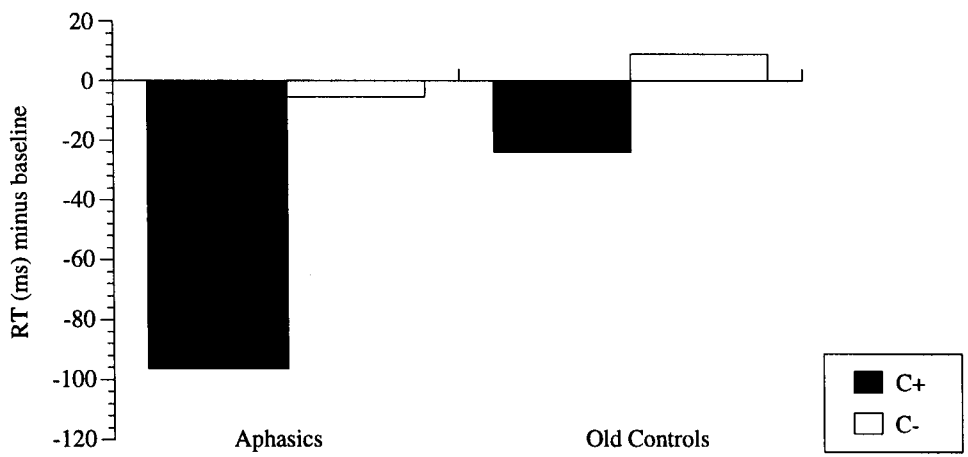


Figure 5 Contextual relationship by group interaction for old controls and aphasics



Indeed, it is fair to say that these aphasic patients experience too much priming, so that they are affected by competitive effects that normals weed out quickly in the comprehension process. Under this interpretation, we might argue that the locus of anomia (at least in these patients) has to do with the unchecked spread of activation. Target words are indeed active, but so are their competitors. The resulting traffic control problem may result in word substitutions, and/or in a failure to come up with the target word quickly.

General Discussion

The present study attempted to shed light on the issue of lexical autonomy and lexical access in normals and anomic patients, by placing word-level priming in competition with discourse-level priming. This design yielded a number of interesting interactions between word-level and sentence-level factors, as follows.

First, there was a reversal of the expected relationship between W+/C+ items and W–/C+ items In contrast to the predictions of an additive model, reaction times were significantly slower when prime and target were related to each other *and* to the discourse context (W+/C+), compared with a condition in which the target fits the context but the prime does not (W–/C+). We explained this counterintuitive finding by postulating a competition between the prime and target for the role of "best completion" at the discourse level. In the W+/C+ condition, both are good completions and therefore the competition between related words is fierce. In the W–/C+ condition, the prime is unrelated to the context and therefore provides no competitive inhibition of the target.

Second, we failed to find "automatic", local priming effects between related words when neither of the words fit the context (i.e. W+/C– items were no faster than neutral controls, where the two words are unrelated to each other and the context). We suggest that this occurs because the discourse context can suppress incongruent word primes, which in turn prevents those primes from exerting a facilitative effect on their single-word targets.

Third, the slowest reaction times of all were observed in the W–/C– condition, where the target is unrelated to the context and to the prime word, but the prime serves as a good completion. We argued that this condition is slower than neutral control items (where nothing is related to anything else) because the prime does indeed serve as a good completion, boosting its activation and suppressing pronunciation of the target word.

It is not clear whether these effects are lexical or post-lexical, a point which is further discussed below. But it is clear that context can have powerful effects on lexical access, in the time window that is usually described in studies that lay claim to automaticity. Furthermore, it is clear that these early context effects involve inhibitory processes, in contrast with previous claims that inhibition always reflects slow, controlled, strategic forms of processing.

The second objective of this study was to observe the changes in language processing that occur with aging and aphasia. Normal aging had a slight but significant impact on

the ability of subjects to perform the cross-modal word pair task. First of all, older adults showed an increase in the size of the competitive inhibition between congruent prime and target (W+/C+ vs. W–/C+). The size of this effect was 48 ms, vs. 21 ms in young adults. Yet this seemingly contradicts results in the literature which indicate that aging should provide a breakdown in inhibition. This can be explained in two ways. The first regards the speed at which words are integrated. Presumably, young college controls are faster at integrating the first word and are less slowed in the pronunciation of the second word. If this were the case then it would be expected that older adults should be approximately twice as slow as young controls. This was not the case. The second possibility is that older adults were unable to adequately inhibit the first word. In this case, a breakdown in inhibition of the prime leads to an increase in inhibition between prime and target. In other words, it is the older adults' inability to suppress the prime that led to the larger competition between prime and target. This is further confirmed by the older adults' increased inhibition in the W–/C– condition. In this case, younger adults are better able to suppress the congruent prime to name the incongruent target.

Results for aphasic patients were somewhat more complex. In terms of competitive inhibition, these subjects are about 300 ms slower than older adults but only show a slight increase in the size of competitive inhibition. This is further evidence against a general slowing-of-processing account. However, these subjects seem to show a huge increase in facilitation. In fact, it is clear that contextually related targets significantly facilitated response (–96 ms in Aphasics vs. ~ –24 ms in older controls). This is reminiscent of a finding reported by Nebes, Boller & Holland (1986) for another population with naming deficits, i.e. patients with Alzheimer's disease. Furthermore, Nebes, Boller, & Holland found that subjects had more difficulty in producing a response for sentences with low and medium cloze probability. The present results further confirm that neurologically impaired patients may benefit from highly supportive contexts. If aphasics are more context-dependent (like the AD patients) than normals, then it may be particularly difficult for them to process items in the neutral control condition, in which (in essence) nothing is related to anything else. If this is the case, then the use of this condition as a neutral control may be misleading, inflating our estimates of facilitation and reducing our estimates of inhibition. Thus (for example), the 16 msec. inhibition effect for W–/C– words in the aphasic patients may be an underestimate.

Is there a better candidate to serve as the neutral control in studies of priming at the discourse level, in aphasic patients or any subject population? In fact, there may be no good solution to this problem (West & Stanovich 1988), since there is no such thing as a "neutral paragraph". This opens an even deeper issue, which was alluded to earlier. How much does the neutral control tell us about the interplay of facilitation and inhibition? In the current experiment, the W+/C+ condition was slower than the W–/C+ condition. At first glance, one would have to conclude that the W–/C+ condition is more facilitated (i.e. incongruent primes facilitate the pronunciation of an unrelated word). This implausible situation led us to propose a competitive inhibition between two words which were attempting to fill the same location in a sentence. This seems to confirm an interactive/activation model of language processing in which selection of a candidate involves inhibition of semantically related neighbors. The results, how-

ever, could be placed within a purely facilitatory model in which activation of one candidate leads to a slower activation of a second candidate. Thus a congruent or incongruent target is slower to pronounce because the system must 'reset' before pronouncing the second word. That is 'inhibition' can arise from the a system which is over-'activated' and must wait for resting state to be reached before activation of a subsequent word. In either case, the present results suggest that language processing may be made up of multiple forms of facilitation and inhibition which sum in ways that appear to be purely inhibitory or purely facilitatory. In this view, facilitation and inhibition observed may be a much more complex and dynamic phenomenon than that which is proposed in traditional automatic/controlled models (Posner & Snyder 1975). In fact, facilitation and inhibition may be two sides of the same coin.

Another more controversial issue surrounding modular systems involves the notion of automaticity. For a process, to be automatic it must occur within a fast timeframe and be absent of strategic processes. Furthermore, facilitation is considered to be a central property of modular automatic systems Thus it is unclear if the effects we have captured are lexical or post-lexical. As was mentioned earlier, the majority of studies have used single-word presentation with a sentence or a single word as a prime. In these studies, it was clear that the locus of the study was the access of the target. In this study, however, we used both of these methodologies together. This presents a problem because the results indicate that both the prime and the target may be affected by the sentence context. For example, the results from the experiments presented show that processing of a contextually relevant word (200 SOA) can slow the naming of the subsequent word. Presumably we could accept that a contextually relevant word is accessed within 200 ms but that this has post-lexical effects on the naming of the target. In other words, does access of the first word slow the integration or access of the second word? Further studies which manipulate SOA, ISI and perhaps even the number of related trials might better disambiguate whether these effects are lexical or post-lexical. What the present study does suggest is that the processes involved in sentence integration are rapid and robust.

The locus of the effects are somewhat disambiguated by the data from anomic aphasics. These subjects showed about the same competitive inhibition effect (54 vs. 47 ms) but where markedly faster for semantically congruent words in general. Thus an impairment in naming which seems to slow processing speed does not have an effect on the competition between two 'good' completions. Thus it seems that natural aging and not mild focal brain damage may be responsible for an impairment in the ability to inhibit good completions. An impairment in access, however, does seem to slow the naming of semantically incongruent words more than semantically congruent words. Thus anomics have more problems with access of incongruous targets. Hence, it is clear that the effects we have captured involve to some extent problems with lexical access (i.e. naming) and not with contextual integration. What the current study seems to suggest is that anomia to some extent is alleviated by the presence of good contextual support. The use of a larger discourse context can provide anomics the type of contextual support necessary for relatively unimpaired language processing.

The present study has provided a number of insights into the language processing of normal, aging and brain-damaged adults. First of all, it has shown that local priming

takes on a very different form when placed in a full sentence context. Specifically, it appears that word-level priming can be overwhelmed by higher forms of priming. Second, these context effects appear to involve rapid forms of inhibition. This form of inhibition may be the product of residual activation of the prime or inhibition of competitors. Third, the word-finding deficits experienced by aphasic patients (and, to a lesser degree, by some older adults) may involve an over-reliance on context, coupled with an inability to suppress inappropriate competitors. Perhaps, the most interesting part of this over-reliance on context is that it led to an apparent increase in facilitation which may actually be caused by the inability of aphasics to inhibit incongruent stimuli (which includes the baseline).

We suggest that current models of on-line psycholinguistic processing should consider more carefully the role of inhibition and facilitation. More specifically, these models should consider the possibility of multiple forms of facilitation and inhibition which can sum across the time window generally employed in psycholinguistic processing. The long-standing debate regarding autonomy vs. interaction may be an oversimplification of the complex and dynamical processes involved in language processing, a finding which was further confirmed by the increase in 'facilitation' in anomics. Finally, it is clear that discourse-level contexts can serve as a vehicle for understanding the nature of processing at the word-level. The future use of these contexts should help to clarify existing questions and propose new possibilities. The current study is only the first step in what will hopefully be a rich new source of information for understanding real-time language processing.

References

Balota, D.A. & R.F. Lorch (1986): "Depth of automatic spreading activation: Mediated priming effects in pronunciation but not in lexical decision". Journal of Experimental Psychology: Learning, Memory & Cognition 12, 336 – 345.

Bates, E., B. Wulfeck & B. MacWhinney B. (1991): "Cross-linguistic studies in aphasia: An overview. Special Issue: Crosslinguistic studies of aphasia". Brain & Language 41, 123 – 148.

Chiarello, C., K.L. Church & W.J. Hoyer (1985): "Automatic and controlled semantic priming: Accuracy, response bias, and aging". Journal of Gerontology 40, 593 – 600.

Cohen, J., B. MacWhinney, M. Flatt & J. Provost (1993): "PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers". Behavioral Research Methods 25, 257 – 271.

Colby, K.M., D. Chrisinaz, R.C. Parkinson, S. Graham & C. Karpf (1981): "A word-finding computer program with a dynamic lexical-semantic memory for patients with anomia using an intelligent speech prosthesis". Brain & Language 14, 272 – 281.

Colombo, L. (1986): "Activation and inhibition with orthographically similar words". Journal of Experimental Psychology: Human Perception & Performance 12, 226 – 234.

Farah, M.J. & M.A. Wallace (1992): "Semantically-bounded anomia: Implications for the neural implementation of naming". Neuropsychologia 30, 609 – 621.

Fodor, J. (1983): The modularity of mind: An essay on faculty psychology. Cambridge, Mass.: MIT Press.

Forster, K.I. (1981): "Priming and the effects of sentence and lexical contexts on naming time: Evidence for autonomous lexical processing". Quarterly Journal of Experimental Psychology: Human Experimental Psychology 33A, 465 – 495.
Foss, D.J. (1982): "A discourse on semantic priming". Cognitive Psychology 14, 590 – 607.
Friederici, A.D. & L. Frazier (1992): "Thematic analysis in agrammatic comprehension: Syntactic structures and task demands". Brain & Language 42, 1 – 29.
Friederici, A.D. & K. Kilborn (1989): "Temporal constraints on language processing: Syntactic priming in Broca's aphasia". Journal of Cognitive Neuroscience 1, 262 – 272.
Gainotti, G., M.C. Silveri, G. Villa & G. Miceli (1986): "Anomia with and without lexical comprehension disorders. First European Workshop on Cognitive Neuropsychology" (1983, Bressanone, Italy). Brain & Language 29, 18 – 33.
Grainger, J. (1990): "Word frequency and neighborhood frequency effects in lexical decision and naming". Journal of Memory & Language 29, 228 – 244.
Hadar, U., C. Jones & C. Mate-Kole (1987): "The disconnection in anomic aphasia between semantic and phonological lexicons". Cortex 23, 505 – 517.
Hagoort, P. (1993): "Impairments of lexical-semantic processing in aphasia: Evidence from the processing of lexical ambiguities". Brain & Language 45, 189 – 232.
Hasher, L., E.R. Stoltzfus, R.T. Zacks & B. Rypma (1991): "Age and inhibition". Journal of Experimental Psychology: Learning, Memory & Cognition 17, 163 – 169.
Hasher, L. & R. Zacks (1988): "Working memory, comprehension, and aging: A review and a new view". In: G.H. Bower, eds., The psychology of learning and motivation. (Vol. 22). San Diego: Academic Press, 193 – 225.
Kolk, H.H. & M.M. Van Grunsven (1985): "Agrammatism as a variable phenomenon". Cognitive Neuropsychology 2, 347 – 384.
le Dorze, G. & J.-L. Nespoulous (1989): "Anomia in moderate aphasia: Problems in accessing the lexical representation". Brain & Language 37, 381 – 400.
Light, L.L. & D.M. Burke (1988): "Patterns of language and memory in old age". In: L.L. Light & D.M. Burke, eds., Language, memory and aging. New York: Cambridge University Press.
Lucchelli, F. & E. de Renzi (1992): "Proper name anomia". Cortex 28, 221 – 230.
Marangolo, P., E. Dipace & L. Pizzamiglio (1993): "Priming Effect In A Color Discrimination Task". Perceptual And Motor Skills 77, 259 – 269.
Marslen-Wilson, W.D. & L.T. Tyler (1987): "Against Modularity". In: J.L. Garfield, eds., Modularity in Knowledge Representation and Natural-Language Understanding. Cambridge, Massachusetts: The MIT Press.
McClelland, J.L. & D.E. Rumelhart (1981): "An interactive activation model of context effects in letter perception: I. An account of basic findings". Psychological Review 88, 375 – 407.
Millberg, W., S.E. Blumstein, D. Katz & F. Gershberg (1992): Semantic facilitation in aphasia: Effects of time and expectancy. Unpublished Manuscript, Boston University School of Medicine, Aphasia Research Center, Boston.
Mitrushina, M. & P. Satz (1991): "Effect of repeated administration of a neuropsychological battery in the elderly". Journal of Clinical Psychology 47, 790 – 801.
Nebes, R.D., F. Boller & A. Holland (1986): "Use of Semantic Context by Patients with Alzheimer's Disease". Psychology and Aging 1, 261 – 269.
Nebes, R.D. & C.B. Brady (1992): "Generalized cognitive slowing and severity of dementia in Alzheimer's disease: Implications for the interpretation of response-time data". Journal of Clinical & Experimental Neuropsychology 14, 317 – 326.
Neely, J.H. (1976): "Semantic priming and retrieval from lexical memory: Evidence for facilitatory and inhibitory processes". Memory & Cognition 4, 648 – 654.
Ober, B.A., G.K. Shenaut, W.J. Jagust & R.C. Stillman (1991): "Automatic semantic priming with various category relations in Alzheimer's disease and normal aging". Psychology & Aging 6, 647 – 660.

Onifer, W. & D.A. Swinney (1981): "Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias". Memory & Cognition 9, 225 – 236.

Ostrin, R.K. & L.K. Tyler (1993): "Automatic access to lexical semantics in aphasia: Evidence from semantic and associative priming". Brain & Language 45, 147 – 159.

Posner, M.C. & C. Snyder (1975): "Facilitation and inhibition in the processing of signals". In: P. Rabbitt & S. Dornic, eds., Attention and Performance. (Vol. V). New York: Academic Press, 669 – 683.

Salthouse, T.A. (1991): "Mediation of adult age differences in cognition by reductions in working memory and speed of processing". Psychological Science 2, 179 – 183.

Seidenberg, M.S., M.K. Tanenhaus, J.M. Leiman & M. Bienkowski (1982): "Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing". Cognitive Psychology 14, 489 – 537.

Tweedy, J.R., R.H. Lapinski & R.W. Schvaneveldt (1977): "Semantic-context effects on word recognition: Influence of varying the proportion of items presented in an appropriate context". Memory & Cognition 5, 84 – 89.

Van Petten, C. & M. Kutas (1987): "Ambiguous words in context: An event-related potential analysis of the time course of meaning activation". Journal of Memory & Language 26, 188 – 208.

Zurif, E., D. Swinney, P. Prather, A. Wingfield & H. Brownell (1992): An on-line analysis of syntactic processing in the elderly. Unpublished manuscript, Brandeis Univesity, Department of Psychology and Center for Complex Systems, Waltham, Massachusetts.