

Semantic Influence on Processing Gender Agreement: Evidence from Hebrew

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In the present study we examined the influence of manipulating the animacy of the sentential subject on the size of the syntactic priming effect induced by violation of subject-predicate gender agreement in Hebrew. The agreement violation delayed naming incongruent compared with congruent predicates. This priming effect was stronger when the sentential subject was an animate than an inanimate noun. Additional experiments revealed that: (1) the interaction between the priming effect and animacy of the subject could not be explained on the basis of differences in the phonological transparency of the gender inflection in the two groups of nouns, and (2) it was sensitive to the ratio of animate/inanimate conditions in a block. We suggest that the interaction between the processing of agreement and the effect of animacy is influenced by a controlled process of verifying the coherence of a currently identified word within a built-up context.

In the present study, we examined the susceptibility of syntactic analysis to nonsyntactic information, focusing on the processing of an agreement rule in Hebrew, a process based on inflectional morphology. Specifically, we examined whether the syntactic analysis of gender agreement between the subject and the predicate is influenced by the semantic feature of animacy of the subject.

With the notable exception of Nicol, Forster, and Veres (1997), the influence of semantic information on the processing of subject-predicate agreement was examined mostly in the context of language production (Bock &

This study was supported by a grant from the Israeli Foundations Trustees to Shlomo Bentin, and by a grant from NICHD (#01994) to Haskins Laboratories.

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Eberhard, 1993; Bock & Miller 1991; Vigliocco, Butterworth, & Garrett, 1996a; Vigliocco Butterworth, & Semenza, 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996b). These studies were carried out in different languages, such as English (Bock & Eberhard, 1993; Bock & Miller, 1991; Nicol *et al.*, 1997; Vigliocco *et al.*, 1996a), Italian (Vigliocco *et al.*, 1995), Spanish (Vigliocco *et al.*, 1996a), Dutch and French (Vigliocco *et al.*, 1996b) and recently Hebrew (Deutsch, 1998). Across languages, however, the findings regarding semantic influences on agreement processing remained equivocal. In English, the general finding is that the process of subject–predicate agreement (i.e., the English rule of number agreement) is unaffected by semantic factors. These findings were based on language production (Bock & Eberhard, 1993; Bock & Miller, 1991) as well as on language comprehension tasks (Nicol *et al.*, 1997). In contrast, a similar experimental paradigm in the context of language production in Italian (Vigliocco *et al.*, 1995), Spanish (Vigliocco *et al.*, 1996a), Dutch, and French (Vigliocco *et al.*, 1996b) revealed opposite results, leading to the conclusion that, in contrast to English, the processing of agreement rules in these languages is sensitive to semantic factors. Similar conclusions were reached by Deutsch (1998) based on a study in Hebrew. That study showed that the inhibitory effect of agreement violation on reading can be overridden by global semantic coherence, providing that there is enough time for semantic or conceptual processes to develop. It appears, therefore, that the inconsistency in the findings could be accounted for by grammatical differences among languages.

Across languages, differences in the susceptibility of subject–predicate agreement processing to semantic factors might be related to the role of inflectional morphology in conveying variations in meaning as well as to the extent to which inflectional morphology and agreement rules are used in the grammar of the languages. For example, in English, inflectional morphology is more limited than in Italian, Spanish, Dutch, French, and Hebrew, and consequently English syntax is more dependent on word order than on morphological devices. Recent data in French and Dutch seem to point to the richness of a language morphology and the frequency of its use a central factor determining the extent of semantic interaction with the processing of agreement (Vigliocco *et al.*, 1996b). Moreover, unlike English, in Italian, Spanish, and Hebrew, the pronoun representing the sentential subject can be omitted from the sentence. In absence of the pronoun, the person, gender, and number identity of the sentential subject is conveyed by inflectional morphemes attached to the predicate (i.e., null subject). Thus, the extraction of conceptual information about the subject in those languages is based solely on the analysis of the semantic meaning of the inflectional morphemes attached to the sentential predicate. As discussed by Vigliocco *et al.* (1995, 1996a), such differences may make the process of analyzing subject–verb agreement more likely to be influenced by the semantic information carried by the morphemes.

The above analysis illustrates how converging and contrasting evidence from languages that share relevant features, but are also different in important respects, may help in discovering the factors that determine whether syntactic processes are isolated from, or interact with, nonsyntactic on-line processes. The present study took an additional step in this direction by examining possible semantic interactions with processing the gender agreement between the subject and the predicate in Hebrew, a Semitic language, with a very different linguistic structure than Indo-European languages. Although, the relative frequency of inflectional morphology (in respect to gender marking) crosses the boundaries of various linguistic branches (Roman versus Germanic), because these are all Indo-European languages, it is possible that they share a common factor (aside of the richness of morphology) that distinguishes them from English. Hence, evidence from Hebrew, which belongs to a different family of languages, may contribute to achieving a more general description of the principles that determine the isolability of syntactic processing from on-line semantic ones.

Most nouns and adjectives in Hebrew are inflected for gender and number. Verbs are also inflected for gender and number (as well as for person and tense, with the exception of the present tense, which is not inflected for person). Inflection is formed by affixation of a suffix and/or a prefix to a base form and often entails changes in the phonological structure of the base form.⁵ The base form to which affixes are appended is the masculine singular form in the nominal system or the masculine singular past, present, or future forms in the verbal system. Hence, in the verbal system, the masculine is a morphologically unmarked form. The feminine-marking morpheme is usually one of the three possible suffixes: *la*, *let* or *lit*, used by both nouns and verbs. For instance the feminine form of *yeled* (masc., sing., a boy) is *yalda* (sing., fem., a girl). Similarly, in the verbal system, the feminine form of a verb such as *napal* (masc., sing., past, fell down) is *napla* (fem., sing.). It should be noted that there are exceptional cases in which feminine nominal forms are not marked by one of the feminine inflectional markers. However, most exceptional cases involve inanimate rather than animate nouns (see the introduction to experiment 2), so that there is a fairly high correlation, in Hebrew, between grammatical gender and semantic gender, i.e., sex.⁶

⁵ The base form itself is usually a complex morphological structure including two nonconcatenated morphemes: a consonantal root (usually a three-consonant sequence) embedded in a word pattern (formed of vowels alone or vowels and consonants).

⁶ We refer to the "unmarked" form in terms of morphological marking and not to the other meaning that an unmarked form may take, i.e., the form used when reference is made for unspecified gender, i.e., for feminine and masculine forms. (In this case the masculine plural, rather than the singular, form is used.)

Agreement rules are based on matching inflectional affixes across words. These rules are a fundamental tool for specifying syntactic relations in Hebrew, which is, therefore, less dependent on word order than other less inflected languages. For example, the agreement rule according to which the subject and the predicate agree in gender and number (and also in person if the predicate is a verb in the past, future, or imperative form) is nearly always an unequivocal cue for specifying the subject and the predicate in a sentence. Thus, a sentence like "The suspicious (male) judge fell down," which translates into Hebrew as: "Hašopet (sub.: article "Ha" + masc. sing., "the judge." The character /ʃ/ stands for the Hebrew fricative, postalveolar phone.) haxaʃdan (attrib.: article "ha" + masc., sing., "suspicious." The character /x/ stands for the Hebrew fricative velar phone.) napal (pred.: masc. sing. past, "fell down") becomes, when referring to a female judge; "Hašopetet haxaʃdanit napla." As can be seen in the example, the masculine singular form is the unmarked form, whereas the feminine forms (noun, adjective, and verb) are marked by one of the three possible suffixes: /et/, /it/ and /al/. It should be noted that, in addition to the subject-predicate agreement, the subject and attribute also agree in gender and number. Unlike subjects and predicates, however, the subject and attribute also agree in their article. Thus, in most sentential structures, the agreement rules provide an unequivocal cue for identifying the various syntactic roles within the sentence.

Although agreement rules are primarily a syntactic tool, using grammatical markers of inflectional morphology to indicate the relationship between words, the syntactic information conveyed by the agreement may also involve information that could be considered semantic, such as number or semantic gender of animate nouns. Usually, it is difficult to disentangle these two roles of inflectional markers. To this end, the gender agreement rule can be helpful. The same inflectional suffixes for marking gender are used for both animate and inanimate nouns. Thus, whereas gender agreement between subject and predicate reflects only grammatical matching for inanimate nouns, it is usually correlated with semantic features when the nouns are animate.

The interrelation between the syntactic rule of agreement and the semantic feature of animacy was examined in the present study through a syntactic priming paradigm. Using mostly naming and lexical decision tasks, previous studies have provided ample evidence that target words are processed faster and more accurately when they are congruent with their syntactic context than when they are not. In particular, syntactic priming induced by gender agreement was demonstrated in several languages with grammatical gender, such as Dutch (Schriefers, 1993), French (Grosjean, Dommergues, Cornu, Guillelmon, & Besson, 1994), and Italian (Bates, Devescovi, Hernandez, & Pizzamiglio, 1996). This effect has also been demonstrated in Hebrew (Deutsch & Bentin,

1994). In addition, the priming effect induced by subject–predicate agreement in Hebrew was recently demonstrated also by monitoring readers' eye movements and recording their electrophysiological activity (Deutsch, 1998; Deutsch, & Bentin, submitted).

In the following experiments, the priming paradigm was applied using a naming task. The naming task was chosen since it was found to be one of the more reaction-time preferable tasks to tap word recognition processes in regular priming settings (Balota & Lorch, 1986; Neely, 1991). Its sensitivity to syntactic priming effect, particularly when induced by sentential context (rather than by single word context) has been demonstrated in previous studies (Boland, 1993, Tanenhaus & Lucas, 1987).

EXPERIMENT 1

In the present experiment we compared the effect of violating the subject–predicate gender agreement for animate and inanimate sentential subjects. The same target word, i.e., the sentential predicate, followed either an animate or an inanimate sentential subject, keeping or violating the rule of agreement, as illustrated in the Method section.

Since the gender carries the additional semantic feature of biological sex only for animate subjects, an interaction between semantic and syntactic processes should elevate the salience of the disagreement in gender between subject and predicate. Hence, such an interaction should enhance the delay in naming syntactically incongruent predicates (relative to congruent ones) when the subject of the sentence is animate than when it is inanimate.

Method

Participants. The participants were 48 undergraduate students. They were all native speakers of Hebrew who took part in the experiment for course credit or for payment.

Stimuli and Design. The critical stimuli in this experiment were 48 target words that constituted the predicates of three-word sentences. All sentences had the structure of a noun phrase (the context) followed by a predicate (the target). The noun phrase consisted of a nominal form, that is, the sentential subject, followed by an attribute. Each target word was embedded in four different sentential contexts: (1) animate–congruent, (2) animate–incongruent, (3) inanimate–congruent, and (4) inanimate–incongruent. In the animate contexts, the subject of the sentence was an animate noun. In the inanimate contexts, the subject of the sentence was an inanimate noun. In the congruent condition the target was inflected to agree in gender with the subject. In the

Table I. Examples of Stimuli in Experiment 1 in Both Congruity Conditions (Congruent/Incongruent) of Animate and Inanimate Sentences for Marked and Unmarked Predicates^a

Experimental condition	Example
Unmarked predicates	
Animate—congruent	Hafopet (sub., masc.) haxafdan (attrib., masc.) napal (pred., masc.) (<i>The suspicious judge fell down.</i>)
Animate—incongruent	Hafopetet (fem.) haxafdanit (fem.) napal (masc.).
Inanimate—congruent	Hayahalom (sub., masc.) hanotzet ^b (attrib., masc.) napal (pred., masc.) (<i>The shiny diamond fell down.</i>)
Inanimate—incongruent	Hamaxrozet (sub., fem.) hanotzet ^b (attrib., fem.) napal (pred., masc.) (<i>The shiny necklace fell down.</i>)
Marked predicates	
Animate—congruent	Hafopetet (fem) haxafdanit (fem) napla (fem.).
Animate—incongruent	Hafopet (masc.) haxafdan (masc.) napla (fem.).
Inanimate—congruent	Hamaxrozet (fem.) hanotzet ^b (fem.) napla (fem.).
Inanimate—incongruent	Hayahalom (masc.) hanotzet ^b (masc.) napla (masc.).

^a Inflectional gender morphemes are printed in bold.

^b The sequence **tz** stands for the alveolar affricative Hebrew phoneme.

incongruent condition the inflection of the target did not agree in gender with the sentential subject.⁷ Each sentential subject (in the congruent as well as the incongruent conditions) was followed by a congruently inflected attribute. The syntactic congruity between the target (predicate) and its sentential context was manipulated within each animacy condition, forming two levels of a syntactic congruity factor.

In order to control for specific effects between the rules of agreement and the morphological markedness, each target word appeared in two different morphological versions: An unmarked version, i.e., the past, singular, masculine form, and a marked version, which was the past, singular, feminine form. This control was important because previous studies suggested that marked and unmarked morphological forms may have differential effects on linguistic processing (Bock & Eberhard, 1993; Eberhard, 1997; Vigliocco *et al.*, 1995). Examples of each of the four experimental conditions are presented in Table I.

In selecting the stimuli, we avoided orthographic and phonemic identity between the inflections indicating subject–predicate agreement within the sen-

⁷ Note that when violating subject–predicate agreement, we created ungrammatical sentences, not ambiguous sentences in which the reader can be misled and then overcome the syntactic implausibility.

tence. This constraint was necessary in order to avoid the possibility of confounding syntactic subject–predicate congruity effects with either rhyming or orthographic repetition effects. Accordingly, we used noun phrases in which the gender inflections of the subject and attributes were different from that of the target. The two words within the noun phrase, however, may have had the same inflectional morpheme.

The resulting 384 sentences (48 targets presented in four context conditions, in masculine and feminine versions) were divided into eight stimulus lists. Each list included 48 different sentences, 12 in each of the four animacy/congruity conditions (six targets in each of these combinations were unmarked and another six were marked for feminine). Six different subjects were randomly assigned to each list. Thus, each subject read sentences in every experimental condition and each target was presented (across subjects) in all conditions. This rotation allowed a three-way analysis of variance (ANOVA) with repeated measures with subjects (F_1) and items (F_2) as random variables. The factors were animacy (animate, inanimate), syntactic congruity (congruent, incongruent), and morphological markedness (marked, unmarked).

Procedure. The sentential context appeared at the center of the screen for 2000 ms, after which the target word was presented for an additional 1000 ms. The context remained on the screen until the end of the trial, and the target was spatially located as a natural continuation of the sentence. Participants were asked to read aloud the context as well as the targets, but speeded performance was required only for the targets. RTs were measured from the onset of the target on the screen until the onset of its naming. The experiment started with a practice session of 16 sentences.

Results

Naming RTs that were shorter than 150 ms accounted for less than 3% of the responses and were discarded. Means and standard deviations were calculated separately for each subject and for each target in each of the conditions. Outlier RTs that were more or less than 2 *SD* from the mean accounted for fewer than 0.5% of the responses and were excluded from the recalculated averages.

The three-way ANOVA showed that morphological markedness had no significant effect on RT [$F_1(1, 47) < 1$, $F_2(1, 47) < 1$] and did not significantly interact with either of the other two factors [markedness \times animacy: $F_1(1, 47) = 2.02$, $MSE = 2046$, $p = .162$, $F_2(1, 47) = 2.53$, $MSE = 2122$, $p = .12$, and markedness \times congruity: $F_1(1, 47) = 1.42$, $MSE = 1393$, $p = .239$, $F_2(1, 47) < 1$]. In light of this pattern, and because the distinction between marked and unmarked versions was introduced primarily as a control

variable, the data were collapsed across morphological markedness and re-analyzed.

The mean naming time for the congruent and incongruent targets in the congruent and incongruent conditions is presented in Table II.

Congruent predicates were named equally fast in the animate and inanimate conditions. Syntactic incongruity led to slower responses. A two-way ANOVA using only the factors of animacy and syntactic congruity showed that the priming effect was statistically reliable in both subject [$F_1(1, 47) = 16.33, MSE = 1311, p < .001$] and item analyses [$F_2(1, 47) = 25.12, MSE = 868, p < .0001$]. Across congruity conditions targets were named more slowly in the animate condition than in the inanimate condition. This effect was statistically reliable in the subject analysis [$F_1(1, 47) = 4.33, MSE = 1369, p < .05$] and borderline in the item analysis [$F_2(1, 47) = 3.68, MSE = 1939, p = .06$]. The congruity \times animacy interaction was significant for subjects [$F_1(1, 47) = 6.43, MSE = 925, p < .05$], but not for items [$F_2(1, 47) = 2.54, MSE = 1994, p = .12$]. Planned comparisons for subject and item means revealed that, whereas the syntactic priming effect was significant for the animate condition [$F_1(1, 47) = 18.73, MSE = 2664, p < .001, F_2(1, 47) = 19.89, MSE = 2408, p < .001$], it was not reliable for the inanimate condition [$F_1(1, 47) = 2.65, MSE = 1808, p = .11, F_2(1, 47) = 1.76, MSE = 3315, p = .19$].

Discussion

The most important outcome of the present experiment was that the syntactic priming effect was greater when the subject of the sentence was an animate noun than when it was an inanimate noun. Although this interaction was significant only in the subject analysis, planned comparisons for items as well as for subjects showed that the priming effect was significant only for animate sentences. Moreover, one of the conditions in experiment 3 (below) replicated the present experiment, revealing a significant interaction between animacy and congruity for both subjects and items. Consequently the results of this experiment confirmed the prediction that the

Table II. Naming Time [$M(SEM)$] for Syntactically Congruent and Incongruent Targets in Animate and Inanimate Conditions in Experiment 1

Congruity Condition	Animacy condition	
	Animate	Inanimate
Incongruent	560 (11.9)	538 (10.3)
Congruent	528 (10.8)	528 (9.3)
Congruity Effect (ms)	32	10

magnitude of the syntactic priming effect is modulated by animacy, supporting the hypothesis that the syntactic processing of agreement is influenced by semantic features of the stimuli.

There are, however, two caveats regarding the above interpretation that should be considered. The first is the possibility that the interaction between the congruity and animacy factors could be explained solely by semantic factors rather than by an interaction between syntactic and semantic processes. This possibility is raised by the unexpected absence of the priming effect when semantic factors were absent, i.e., in the inanimate condition. We would claim, however, that this interpretation is unlikely. Ascribing the priming effect in the animate condition solely to semantic factors would imply that the basic semantic relations between the subject and the predicate are different in the congruent and the incongruent conditions. Note, however, that exactly the same sentences were used for both conditions. The only difference was in the inflectional morphology of the subject, with no change in either the basic meaning or the semantic relationship between the subject and the predicate (except that entailed by the gender of the predicate). Therefore, in order for a reader to notice the gender incongruity, he/she must analyze the morphological form of the inflection. Thus any semantic effect that might have mediated the priming effect in the animate condition must have been based on a morphological elaboration of both the subject and the predicate and the application of the rule of agreement. Furthermore, the same target words were used for both animate and inanimate sentence subjects in each of the congruity conditions. The targets and their relationship with the context were chosen very carefully, so that none of the targets were semantically or associatively related to the preceding words or could have been predicted on the basis of the semantic context. If there had been any systematic semantic bias between the animate and inanimate congruent nouns, it would have been reflected in different reaction times for these two groups. In contrast, the mean naming time for congruent targets in the animate and inanimate conditions was identical (528 ms).

The second caveat is the possibility that the absence of the priming effect for the inanimate subjects was related to a difference in gender marking regularity of animate and inanimate nouns rather than to semantic factors. Although the masculine is usually the unmarked form and the feminine is usually marked by a feminine morpheme, exceptions from this regularity exist and are more frequent for inanimate than for animate nouns. Consequently it is possible that the gender-inflection is a more salient grammatical feature for animate than inanimate nouns and, therefore, the absence of the priming effect in the latter condition could be accounted for by the reduced morphophonological transparency of the gender marking. Because the regularity of the inanimate nouns in the present experiment was not controlled and post

hoc analyses would be based on too few items, experiment 2 was designed to examine this hypothesis directly.

EXPERIMENT 2

The irregularity of the inflectional system associated with gender is manifested either in the singular or in the plural nominal forms for animate and inanimate nouns. However, these exceptions are considerably more common in inanimate nouns, particularly in regards to the plural, as demonstrated by the examples below.

Hebrew uses two suffixes to denote plurality: one that is regularly used for masculine */im/* and one regularly used for feminine */ot/*. Exceptions to this regularity are masculine forms that take the usually feminine plural morpheme */ot/*, such as: *mazleg* (masc., sing.) meaning *a fork*—*mazlegot* (masc., pl.), or feminine forms that take the usually masculine plural morpheme */im/*, such as: *pnina* (fem., sing.) meaning *a pearl*—*pninim* (fem., pl.). Although for the sake of completeness, the examples above included both masculine and feminine nouns, exceptions are much more common in masculine forms. There are about 70 examples (among them only eight animate nouns) of feminine nouns that take the suffix */im/* in their plural form, and more than 200 examples of masculine nouns that take the suffix */ot/* in their plural form (among them only seven animate nouns).

Since the correlation between the inflectional structure and the grammatical gender is weaker for inanimate than for animate nouns, it is possible that the salience of the grammatical gender of inanimate nouns is less conspicuous than of animate nouns. Thus, the extraction of the gender conveyed by inanimate words might be harder (or less specified) than of animate words and, consequently, the native speaker would be less disturbed by gender disagreement in the case of inanimate nouns than of animate nouns. This hypothesis was supported by studies in Italian, which showed that gender classification was harder for words in which gender marking was phonologically ambiguous, as was revealed by a gender monitoring task for single words (Bates, Devescovi, Pizzamiglio, D'Amico, & Hernandez, 1995) as well as in a syntactic priming paradigm for adjective (prime)–noun (target) agreement (Bates *et al.*, 1996).

In the present experiment we compared the syntactic priming effect for regular and irregular nouns in order to explore the possibility that the effect of animacy on agreement processing observed in experiment 1 might have been accounted for by the differences in morphophonological transparency between animate and inanimate nouns. As in the previous experiment, syntactic priming was induced by violating the subject–predicate gender agree-

ment. Unlike in experiment 1, however, in the present experiment only inanimate nouns were used and the regularity of these nouns was manipulated. If the difference between the syntactic priming for animate and inanimate subjects reflects mainly the difference between processing inflectional regular and irregular word categories, syntactic priming should be found only for regular forms.

Method

Participants. Forty-eight undergraduate students, who had not participated in experiment 1, were tested. They were all native speakers of Hebrew who took part in the experiment for course credit or payment.

Stimuli and Design. The stimuli included 48 target words. Each target word was embedded in four different sentential contexts: regular-congruent, regular-incongruent, irregular-congruent, and irregular-incongruent. Since, as mentioned above, most examples of irregularity are in the plural form of masculine nouns, all noun phrases were of a masculine singular form (followed by an attribute). In order to keep the conditions of the present experiment as similar as possible to these of experiment 1, the regular and irregular nouns appeared in their singular form and not in their irregularly inflected plural form. Note, that if the irregular plural form had been used, it might have biased the congruent condition of the irregular form. This is because a typically feminine suffix would have appeared followed immediately by a typically masculine suffix. This bias might have inhibited naming latency of the congruent irregular condition, causing an underestimation of the priming effect induced by the incongruent irregular forms. On the basis of these considerations, the sentences in the present experiments were of the structure (shown in Table III).

Table III. Examples of Stimuli Used in Experiment 2 in Both Congruity Conditions (Congruent/Incongruent) for Regular and Irregular Inanimate Sentences^a

Experimental condition	Example
Regular—congruent	Hayahalom (sub., masc.) hanotzetz (attrib., masc.) napal. (<i>The shiny diamond fell down.</i>)
Regular—incongruent	Hayahalom (sub., masc.) hanotzetz (attrib. masc.) napla (pred., fem.).
Irregular—congruent	Hamazleg (sub., masc.) hanotzetz (attrib., masc.) napal (pred., masc.). (<i>The shiny fork fell down.</i>)
Irregular—incongruent	Hamazleg (sub., masc.) hanotzetz (attrib., masc.) napla (pred., fem.).

^a Inflectional gender morphemes are printed in bold.

Moreover, since most irregular nouns are masculine, we could not manipulate the agreement between the subject and the predicate by changing only the noun phrase (context) and keeping the predicate (target) intact. Therefore, unlike in the previous experiment, in which the same inflectional form of the target was used in both congruity conditions, in the present experiment the target word, i.e., the predicate, was inflected as a masculine singular form in the congruent condition and as a feminine singular form in the incongruent condition.

Each subject was examined in all four conditions, using different targets in each condition. This design allowed a within-subject (F_1) and within-item (F_2) ANOVA design with regularity (regular, irregular) and syntactic congruity (congruent, incongruent) as independent variables.

Procedure. Experimental procedure of experiment 2 was identical to that of experiment 1.

Results and Discussion

As in experiment 1, responses that were shorter than 150 ms (fewer than 4% of the responses) and outliers of more than 2 *SD* from the mean (fewer than 3%) were excluded.

Unlike in experiment 1, in the present experiment, a significant syntactic priming effect was observed for inanimate nouns and was, in fact, similar in its size to the effect obtained for animate nouns in experiment 1 (about 30 ms). This effect was found for both regular and irregular nouns (Table IV).

A two-way ANOVA showed that the syntactic priming effect was significant [$F_1(1, 47) = 22.94$, $MSE = 2036$, $p < .001$, $F_2(1, 47) = 18.06$, $MSE = 2887$, $p < .001$] and that there was no significant effect of regularity [$F_1(1, 47) = 1.54$, $MSE = 1709$, $p > .05$, $F_2 < 1$]. Most importantly, the size of the effect was not influenced by the morphological regularity of the sentence subject, as reflected by the nonsignificant interaction between the factors of regularity and congruency [$F_1 < 1$, $F_2 < 1$]. Consequently, the

Table IV. Naming time [M (SEM)] for Regular and Irregular Inanimate Targets in Syntactically Congruent and Incongruent Context in Experiment 2

Congruity Condition	Regularity condition	
	Regular	Irregular
Incongruent	632 (12.1)	637 (12.8)
Congruent	599 (13.0)	609 (11.9)
Congruity effect (ms)	33	28

present results suggest that the observed difference between animate and inanimate nouns in experiment 1 was not mediated by morphophonological factors.

A possible account for the existence of a priming effect in the present experiment, despite its absence in the inanimate condition of experiment 1, is suggested by the observation that the outcome of the animate and the inanimate conditions of experiment 1 differed only in the naming of incongruent targets. Accordingly, it is possible that the interaction between syntactic congruity and animacy was mediated by strategic processes related to the inhibition induced by processing the incongruity. This possibility was examined and further elaborated in experiment 3.

EXPERIMENT 3

In a previous study, Deutsch and Bentin (1994) showed that the syntactic priming effect induced by subject-predicate agreement includes both inhibitory and facilitatory components. Moreover, since only the inhibition was modulated by experimental manipulations that tap automatic and strategic processes, they suggested that, whereas both the facilitation and the inhibition were based on an automatically initiated process of testing the sentential coherence, the inhibitory component was related, in addition, to a strategically controlled phase of reevaluating the incongruent structure.

In order to keep the design as similar as possible to that of experiment 1, we did not include a neutral condition in the present study. Nonetheless, on the basis of our previous study, in which the same syntactic manipulations were made while a neutral condition was included (Deutsch & Bentin, 1994), our working hypothesis was that the delay of naming incongruent targets in the present study reflected inhibition. Hence, the difference between the effect of semantic information on the processing of incongruent targets observed in experiments 1 and 2 might be explained by a strategic mechanism that mediated that inhibition. Note that unlike in experiment 2, in which all the sentences included inanimate subjects, in experiment 1 the animate and inanimate conditions were randomly intermixed. It is possible that the mixing of animate and inanimate conditions accentuated the semantic difference between these two types of sentences and therefore enhanced the overall incongruity of the animate relative to inanimate sentences. The enhanced incongruity may have extended the process of reevaluating animate sentences while diminishing the impact of gender incongruity in inanimate sentences. On the other hand, presenting the inanimate condition in a separate block should deemphasize the factor of animacy, revealing only the syntactic incongruity.

As a direct test of the above hypothesis, in the present experiment we compared the interaction between syntactic priming and animacy in both a mixed and a blocked presentation design. The stimuli were the same as those used in experiment 1, so that the mixed mode of presentation was a replication of experiment 1. In the blocked mode of presentation, the animate and inanimate conditions were presented in separate blocks. If the response to incongruent targets indeed reflects an inhibitory process that could be augmented by shifting the participants' attention to semantic factors in the mixed presentation, then that mode of presentation should interact with the animacy effect on the identification of incongruent targets. This interaction should reflect a stronger animacy effect on the syntactic priming in the mixed relative to the blocked mode of presentation.

Method

Participants. The participants were 128 undergraduate students who had not participated in any of the previous experiments. Half of the participants were tested in the mixed mode and the other half in the blocked mode of presentation. They were native speakers of Hebrew, taking part in the experiment for course credit or payment.

Stimuli and Design. The stimuli were those used in experiment 1. In the mixed presentation condition, the 24 animate and 24 inanimate sentences (12 congruent and 12 incongruent for each animacy condition) were presented in one block. The sentences within the block were differently randomized for each participant. In the blocked presentation condition, the animate and inanimate sentences were presented in different blocks of 24 sentences each. The sentences in each of the two blocks were differently randomized for each subject. Hence, in addition to the three factors examined in experiment 1, the factor of mode of presentation was added to the present design.

Procedure. The procedure used for the mixed presentation was identical to that used in experiment 1. In the blocked presentation, 32 participants began with the animate block and 32 with the inanimate block. One training session of 16 sentences (animate and inanimate) preceded the presentation of the two blocks. A short intermission separated the two blocks. No special instructions were given between the first and the second block.

Results

RTs that were shorter than 150 ms accounted for 7.5% of the responses and were discarded. Means and standard deviations were calculated for each participant and each target in each of the conditions. Outliers (based on sub-

ject or item means in each condition) of more than 2 *SD* accounted for less than 0.4% of the responses and were excluded from the recalculated averages.

As in experiment 1, no main effect of morphological markedness was found in the four-way ANOVA [$F_1(1, 126) = 1.72$, $MSE = 1720$, $p = .192$, $F_2(1, 47) < 1$]. Therefore, as in experiment 1, the data were collapsed across the marked and unmarked targets.

The means for naming congruent and incongruent predicates in the animate and inanimate conditions for each presentation mode (mixed and blocked), are presented in Table V.

As in experiment 1, in the mixed presentation mode, the syntactic priming effect was much larger in the animate (29 ms) than in the inanimate condition (12 ms). As predicted, presenting all inanimate sentences in one block enhanced the syntactic priming effect for the inanimate condition. An unpredicted outcome, however, was that the syntactic priming effect for animate sentences was reduced in the block presentation compared to the mixed presentation. In addition, as predicted by the "strategic hypothesis," the mode of presentation affected the naming latency of incongruent but not congruent predicates.

Animacy (animate, inanimate) \times syntactic congruity (congruent, incongruent) and mode of presentation (mixed, blocked) ANOVAs for subjects (F_1) and items (F_2) were used to test the statistical reliability of the above differences. The influence of presentation mode on the interaction between the congruity and animacy was reflected by a significant second-order interaction between all three factors in the subject analysis [$F_1(1, 126) = 4.69$, $MSE = 1008$, $p < .05$], but not in the item analysis [$F(1, 47) < 1$]. Additional analyses of syntactic congruity and animacy separately for each presentation mode were done to further explore possible effects of the mode of presentation.

As in experiment 1, the interaction between syntactic congruity and animacy was significant in the subject analysis [$F_1(1, 63) = 4.55$, $MSE = 978$, $p < .05$]. Furthermore, reinforcing the previous results, the item analysis in this experiment was significant as well [$F_2(1, 47) = 4.36$, $MSE =$

Table V. Naming Time [M (SEM)] for Syntactically Congruent and Incongruent Targets in Animate and Inanimate Conditions—Blocked and Mixed Presentation—in Experiment 3

Congruity Condition	Mixed		Blocked	
	Animate	Inanimate	Animate	Inanimate
Incongruent	534 (9.9)	515 (8.7)	521 (9.7)	530(10.8)
Congruent	505 (7.9)	503 (8.9)	505 (9.6)	506(10.0)
Congruity Effect (ms)	29	12	16	24

1078, $p < .05$]. Planned comparisons revealed that for the animate condition the priming effect was significant [$F_1(1, 63) = 25.32$, $MSE = 2169$, $p < .001$, $F_2(1, 47) = 15.06$, $MSE = 2603$, $p < .001$]. In the inanimate condition, the priming effect was significant in the subject but not the item analysis [$F_1(1, 63) = 5.26$, $MSE = 1940$, $p < .05$, $F_2(1, 47) = 1.93$, $MSE = 1893$, $p = .17$].

In contrast to the mixed presentation, in the blocked presentation condition there was no significant interaction between animacy and syntactic congruity [$F_1(1, 63) < 1$, $F_2(1, 47) < 1$]. The priming effect was statistically significant in the inanimate [$F_1(1, 63) = 17.16$, $MSE = 2102$, $p < .001$, $F_2(1, 47) = 6.14$, $MSE = 2366$, $p < .05$] as well as the animate conditions [$F_1(1, 63) = 9.60$, $MSE = 1936$, $p < .005$, but $F_2(1, 47) = 3.23$, $MSE = 7014$, $p = .08$].

Discussion

The present experiment yielded two important results. First, it replicated the interaction between semantic factors and syntactic processing suggested by experiment 1 and ruled out the concern raised by the nonsignificant item analysis of the interaction in that experiment. This result supports the hypothesis that semantic information influences the analysis of grammatical agreement. The second important result was that this interaction was found only when the animate and inanimate conditions were mixed. When sentences with animate or inanimate subjects were separated in different blocks, the size of the syntactic priming effect was similar for both sentence types. This pattern supports the hypothesis that the interaction between semantic information and syntactic processes can be controlled by strategic factors.

The strategic aspect of the syntactic priming effect in the present study was further supported by the fact that both animacy and mode of presentation factors affected only the responses to incongruent targets. These results are compatible with the suggestion that the delayed responses to incongruent targets reflected an inhibitory process of reevaluating the sentence structure, and as such are sensitive to strategic factors (Deutsch & Bentin, 1994). Assuming that the mixing of sentences with animate or inanimate subjects accentuated the distinction between the two types, the present data suggest that the process of reevaluation is more difficult when the semantic implication of the syntactic violation is more conspicuous. Supposing that in real-life discourse animate and inanimate nouns are mixed, it is conceivable that in highly inflected languages semantic factors interact with structure analysis during language comprehension, at least when agreement rules are violated.

The unpredicted reduction of the priming effect for the animate condition in the blocked relative to the mixed mode could also be explained by the above suggested "conspicuousness" rationale. The same strategic process that in the

mixed mode reduced the inhibition resulting from pure syntactic violation (in the inanimate condition), might also have overemphasized the consequences of syntactic violations with semantic implications (in the animate condition). This hypothesis is in agreement with the well-documented influence of the ratio between congruent (or related) to incongruent (or unrelated) trials on priming. Specifically, it has been shown that reducing the ratio of congruent to incongruent trials results in a decrease of the inhibition effect, presumably by discouraging expectations for congruency (Fischler & Bloom, 1985; Stanovich & West, 1983). Whereas in the mixed condition only 25% of the sentences were syntactically incongruent animate sentences, they appeared in 50% of the trials in blocked presentation condition. Hence, the expectation of the subjects to read a syntactically congruent animate sentence in blocked presentation mode was reduced relative to the mixed mode.

GENERAL DISCUSSION

In the present study we examined the influence of semantic factors on syntactic processing of gender agreement in Hebrew. Differences in naming gender-incongruent vs. congruent predicates indexed syntactic processing, and the interaction between this syntactic priming effect and the animacy of the subject indexed the involvement of semantic information on the processing of the agreement. Across three experiments, the responses to the predicates were faster in the grammatically correct than in the grammatically invalid sentences. However, the most important result was that this syntactic priming effect showed an intricate pattern of interactions with the semantic factor of animacy.

When the animate and inanimate conditions were mixed, gender incongruity delayed the naming of the predicate significantly more in sentences in which the subject was animate than in sentences in which the subject was inanimate. We accounted for this interaction assuming that the violation of agreement for animate nouns is more conspicuous because, in addition to the grammatical violation, it also entails a semantic mismatch between the biological sex denoted by the subject and the incongruently inflected predicate. According to this interpretation, the present data support the hypothesis that the processing of agreement in Hebrew is sensitive to the semantic information. Hence, the outcome of the present study conforms to conclusions reached in studies in which the sensitivity of the agreement processing to semantic information was examined in non-Semitic languages such as Italian, Spanish, Dutch, and French. The fact that similar conclusions were reached in different Indo-European and Semitic languages, but not in English, supports the hypothesis that the susceptibility of the syntactic process of agreement to the

influence of semantic information is determined by the richness and complexity of the morphology. A rich morphology seems to be the only factor that is common to all the languages in which the effect of semantic manipulations interacted with the processing of rules of agreement, and it distinguishes these languages from English.

A cue for how and when during sentence processing semantic factors might affect the process of gender agreement was given by the fact that the interaction between syntactic priming and animacy was restricted to incongruent predicates and by its disappearance when the animate and inanimate conditions were presented in separate blocks. A possible interpretation of this pattern is that it was mediated by late-acting processes in sentence comprehension, processes that can be modulated by attention. Such processes could, for example, be the sentence reanalysis induced by the violation of syntactic congruency (Fodor & Inoue, 1994; Frazier, 1987). The extent and duration of this process could be augmented by a semantic mismatch discovered while lexical-semantic and syntactic information are mapped onto each other (Friederici, 1995).

Such an interpretation is also compatible with Deutsch and Bentin's account of the syntactic priming effect induced by the manipulation of subject-predicate agreement in auditory word identification. On the basis of the observed differences in the influence of manipulations commonly used to distinguish automatic from controlled processes, Deutsch and Bentin (1994) suggested that both the facilitatory and the inhibitory components of the syntactic priming effect are anchored in the listener's (or reader's) covert assumption that language messages are coherent ("the assumption of coherence"; cf. deGroot, Thomassen, & Hudson, 1982). When these expectations are confirmed, the integration of the on-line-processed word in the ad-hoc-formed structure is easy, and therefore the ultimate process of identifying the word is facilitated. If the morphologic structure of the word is incongruent with the expectations, an additional process of reevaluating the built-up structure of the sentence and/or the word to be identified is initiated, delaying the processing of incongruent targets. The veiled controlled aspect of this late process of sentence verification has been recently supported in an ERP study of syntactic incongruity (Hahne & Friederici, 1999).

The interaction found in the present study between the processing of animacy and the subject-predicate agreement can also be interpreted using the "competition model" developed by Bates and MacWhinney (1982, 1989) on the basis of cross-linguistic research. According to this model, different cues, whether syntactic (such as agreement rules, case marking, and word order) or nonsyntactic (such as animacy and agency), compete during the on-line processing of the sentence. The relative importance of each cue in controlling the identification of the sentence subject is determined by the

cue validity, i.e., "how often the cue is present when a given interpretation has to be made" and cue reliability, i.e., "when the cue is available, how often it leads to the right answer." The validity of a given cue may differ between languages, as well as within a language, depending on the contextual conditions (Li, Bates, & MacWhinney, 1993). Using this terminology, the Hebrew subject-predicate agreement rule is a highly valid and very reliable cue (see above). However, the semantic feature of animacy is probably also an important cue for subjecthood, as was demonstrated in various studies, including Hebrew (Osgood & Bock, 1977; Sridhar, 1988). Explaining the present results in terms of the competition model, one may postulate that in the congruent case, the syntactic process of subject identification was dominated by the subject-predicate agreement cue. This cue could not dominate the assignment of the subject in the incongruent condition, since the agreement was violated. Consequently competing (semantic) cues (such as the tendency to assign to the subject role an animate noun) may have become more prominent in the incongruent condition. Note, however, that this semantic information was provided only in the animate condition. Hence, it is possible that the syntactic gender incongruity was more conspicuous in the animate condition because participants implicitly used animacy in the process of sentence parsing.

Using the rationale of the competition model, we may also explain the different effect that blocking the stimuli had on the syntactic priming effect in the animate and inanimate sentences.⁸ Whereas in the mixed condition sentence processing takes into account both syntactic and semantic cues for sentence parsing, in the blocked condition, the processor may narrow its range to only the available information. In the inanimate block, the parser is tuned to detect relevant syntactic information. Hence, compared to the mixed condition, the saliency of syntactic incongruence is amplified and therefore the syntactic priming effect is enhanced. In the animate condition, the parser is tuned to use primarily semantic information to parse the sentence. Consequently, compared with the mixed condition where both types of cues are used, in the animate condition the saliency of syntactic incongruity is reduced, leading to a reduced priming effect. Note that such an interpretation is based on our basic assumption that there are strategic factors that may govern sentence processing.

Before concluding this discussion there is an additional issue that, although not at the focus of this paper, is worth mentioning. This issue relates to the finding that the syntactic priming effect was not affected by the regularity of the gender inflection. As discussed in experiment 2, this finding indicates that observed interaction between the animacy of the sub-

⁸ We thank Gabriella Vigliocco for suggesting this interpretation.

ject and the syntactic priming effect cannot be explained solely on the basis of processes of form-matching governed by statistical regularities. Rather, it suggests that the processing of agreement involves lexical information as well as the specification of the grammatical and the semantic features of the words. This suggestion may fit Levelt's model (1989), according to which word gender (as well as word meaning) is part of the word lemma, distinguished from the word's morphophonological form.

In conclusion, the results of the present study indicate that the processing of subject-predicate agreement in Hebrew is influenced by semantic factors, at least as it is reflected in naming. These findings are in accord with previous studies in morphologically rich non-Semitic languages and, in concert with these studies, they support the hypothesis that semantic and syntactic information may be used interactively during syntactic analysis. A detailed examination of the present results across experiments suggested that this interaction might be related to a veiled controlled process of verifying the coherence of a currently identified word within the on-line built-up sentential message. At that processing phase various competing cues, both syntactic and nonsyntactic, may influence the process of sentence parsing.

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