Lexical and Semantic Influences on Syntactic Processing

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The present study addressed the issue of the independence of syntactic processing from lexical and semantic processing. Syntactic (inflectional) priming was manipulated by preceding verb, adjective, and pseudoword targets with noun phrases that either agreed or disagreed in gender and/or number with the target. In Experiment 1, similar syntactic priming effects were found whether the target was a word or a pseudoword. For both, subjects' decisions that targets were the same/different to a probe were faster for targets that were syntactically congruent with their sentential context than for incongruent targets. In Experiment 2, there was a congruency effect for gender: Naming a target that did not agree in gender with the preceding noun phrase was delayed relative to naming a congruent target, but only if the noun phrase's subject was animate. For inanimate targets, syntactic congruency had no statistically significant effect. We suggest that inflectional analysis may not require the full activation of a lexical entry initially; however, subsequent syntactic analysis does interact with a word's semantic information.

The issue of the autonomy of syntactic processing in language perception is controversial. Some authors, adopting a modular approach to the structure of the linguistic system, suggest that communication between syntactic and other cognitive levels of analysis is independent and takes place only at the output of the respective modules (Fodor, 1983; Forster, 1979). An alternative, interactive, view posits mutual influence between the different cognitive domains throughout the processing of the linguistic input (McClelland, 1987; Marslen-Wilson & Tyler, 1987; Tanenhaus, Spivey-Knowlton, Eberhard, Sedivy, 1995).

The autonomy of syntactic processes in sentence comprehension has been supported by studies using a variety of techniques such as self-paced word-by-word reading, or the examination of eye movements during the reading of sentences that were syntactically ambiguous (e.g., Ferreira & Henderson, 1990; Mitchel, 1987; Ferreira & Clifton, 1986; Rayner, Carlson, Frazier, 1983). Syntactic (but not semantic) ambiguity was formed in these studies by using, for example, a reduced relative clause (e.g., "The performer sent the flowers was very pleased") or using sentences in which there was an attached prepositional phrase (e.g., "The spy saw the cop with a revolver") (see Rayner, et al., 1983). These studies revealed that when the reader encounters the disambiguating part of the sentence, the pace of reading is reduced and the reader's gaze regresses (a garden path effect). For the present perspective, the important aspect of the garden path effect was that it was observed even when the semantic characteristics of the sentence were unambiguous (as in the examples above). Consequently, Rayner et al. (1983) suggested that sentence processing, is initially governed by syntactic parsing based on the minimal attachment principle (Frazier & Rayner, 1982), and that it is independent of semantic
or pragmatic constraints. Similar results were obtained manipulating the animacy of the first noun phrase, thus influencing the thematic role that it performs (Ferreira & Clifton, 1986), or using verb subcategorization to constrain the syntactic analysis of ambiguous sentences: for example, using verbs that ‘prefer’ a noun-phrase or a sentence complement (Ferreira & Henderson, 1990; Mitchell, 1987, 1989). These studies supported the syntactic autonomy by revealing a garden path effect in eye movements (hence indicating the application of the minimal attachment principle) regardless of the animacy of the noun or the type of the verb. Finally, additional support for a functional and possibly neuroanatomical dissociation between the syntactic and semantic systems was recently provided by event-related potential (ERP) studies of semantic and/or syntactic processing (Munte, Heinze, & Mangun, 1993; Rosler, Putz, Frederici, & Hahne, 1993). These studies demonstrated that violation of the syntactic integrity of sentences modulates ERPs that have a different scalp distribution and latency than the N400 potential which is modulated by semantic incongruence.

In contrast to the above evidence, other studies, suggested an interaction between syntactic and semantic processing during sentence comprehension. For example, Taraban and McClelland (1988) found that, contrary to the minimal attachment principle, the attachment of the prepositional phrase was initially influenced by content based expectations. In a self-paced reading task in sentences with ambiguity induced by prepositional attachment, they showed that the reading rate at various parts of the sentence was a function of the consistency between the reader’s context-based expectations for a specific attachment (whether minimal or non-minimal), and the ultimate structure of the sentence, rather then being related to the specific syntactic structure of the sentence. Thus, by biasing the sentential context with pragmatic cues into minimal or nominal attachment, it is possible to eliminate the difficulties which may be occasionally observed in sentences with a prepositional attachment that is inconsistent with the minimal attachment principle. Similar conclusions were reached in additional studies. In an attempt to replicate the Ferreira and Clifton (1986) study, Trueswell, Tanenhaus, and Garsney (1994) found that the animacy of the noun significantly constrained the initial parsing of ambiguous sentences with a reduced relative. It is possible however, that the discrepancy between Ferreira & Clifton (1986) and Trueswell et al. (1994) results is accounted for by a difference between the materials used in these two studies. Unlike the first, Trueswell et al. (1994) avoided using inanimate nouns that could be the subject of active verbs (such as, for example, instruments). They also avoided using verbs with ergative meanings that could form acceptable predicates of inanimate nouns (such as, for example, “The trash smell...”).

Also contradictory to the hypothesis of autonomous syntactic processing were further studies in which sub-categorization of verbs was found to guide syntactic parsing (Holmes, Stow, & Cupples, 1989; Stowe, 1989). For example, Stowe (1989) found that the sub-categorization preference of causative verbs can be influenced by the animacy of the subject. In that study the garden-path effect was eliminated in ambiguous sentences such as “While his mother was drying off the boy began to go in,” by replacing the first noun in the subordinate clause (“mother” in the above example) with an inanimate noun (for example, “towel”). Hence, the noun’s animacy biased the subcategorization of the verb from transitive to intransitive and, consequently eliminated the garden-path effect by eluding a subject-verb-object parsing of the sentence. Hence, it is possible that some of the contradictory findings about syntactic autonomy is explained by difficulties in determining the role that certain semantic manipulations may have on the construction of the thematic roles of syntactic units and, consequently, on the syntactic parsing of the sentence.

A different approach taken to study syntactic processing in general and the question of its independence from other linguistic processes, in particular, was the investigation of syntactic context effects on word recognition and lexical decision. Taking this approach, ample evidence have been provided showing that, regardless of semantic relationship, target words are processed faster and more accurately when their inflectional forms are congruent with the syntactic context in which they appear than when they are syntactically incongruent (Careello et al., 1988; Goodman, McClelland, & Gibbs, 1985; Gurjanov, Lukatela, Moskovlević, Savić, & Turvey, 1985; Katz, Boyce, Goldstein, & Lukatela, 1987; Marslen-Wilson, 1987; Seidenberg et al., 1984; Sereno, 1991; Tanenhaus, Leiman, & Seidenberg, 1979; West & Stanovich, 1986). In addition, the idea of
 Independence of Lexical, Semantic and Syntactic Processing

In addition, the idea of independence between syntactic and semantic processes has been supported by several studies that have shown that the syntactic priming effect has different characteristics than the well-known effect of semantic priming (Careollo, Lukatela, & Turvey, 1988; Goodman, McClelland, & Gibbs, 1981; Gurjanov, Lukatela, Mosković, Savić, & Turvey, 1985; Katz, Boyce, Goldstein, & Lukatela, 1987; Seidenberg, Waters, Sanders, & Langer, 1984; Tyler & Wessels, 1983; West & Stanovich, 1986). For example, whereas semantic priming effects are usually found in both naming and lexical decision, syntactic priming effects were not found in naming (Careollo et al., 1988; Seidenberg et al., 1984), or were very small (Stanovitch & West, 1986). Moreover, while semantic priming requires, by definition, the manipulation of lexical units such as base-word, several studies in Serbo-Croatian have shown that a lexical decision to a noun was faster if it was preceded by congruently inflected pseudo-adjective (a nonword inflected like an adjective) than if the noun and pseudo-adjective were syntactically incongruent (Gurjanov et al., 1985; Katz et al., 1987). Hence, in contrast to semantic priming, syntactic priming based on inflectional morphology can be obtained even if the stem of the prime is not included in the lexicon. To the best of our knowledge, there is no direct evidence for the interactive view which is based on studies of syntactic priming.

In the present study we used the syntactic priming effect to explore possible interactions between syntactic and lexical or semantic processes. To this end we focused our research on the effects of violating agreement rules that are anchored in Hebrew inflectional morphology.

Hebrew is a highly inflected language. Most nouns (with the exception of a few categories like collective nouns and proper names) and adjectives are inflected for gender and number. Similarly, all verbs are also inflected for gender and number (as well as for person, tense, aspect, etc., with the exception of the present tense which is not inflected for person). Inflection is formed by affixation (mostly by suffixes) of a base-form which itself is a combination of two morphemes: a consonantal root (usually a three-consonant sequence) and a word-pattern of vowels superimposed on the consonants. For example, the consonantal sequence Y-L-D is combined with a vowel pattern to produce the masculine word YELED (boy). In order to transform this (unmarked) form into the feminine form (i.e., girl), a specific vowel pattern that includes the feminine suffix /'a/ replaces the unmarked (masculine) form’s pattern to produce YALDA. A further vowel pattern transformation produces the derived form YALDUT (childhood). Note that the tri-consonant sequence remains invariant while the vowel pattern changes. Occasionally, as in the last example, the transform includes additional consonants (see Frost & Bentin, 1992 for description of the structure of Hebrew words).

In Hebrew the masculine singular form constitutes the unmarked form. The feminine gender is marked usually by one of three possible suffixes /'a/, /'et/, or /'et/ and the plural is marked by the suffix /'om/ (usually used for masculine) and /'et/ (usually used for the feminine). Frequently, the addition of inflectional affixes also changes the infixed word structure. For example, "yalda" (girl) is the feminine form of "yalde" (boy). Note that y-l-d is the root which is common of both words and that the addition of the suffix ‘a’, denoting the feminine, induced a change in word structure. On the other hand, the masculine form “shofet” (judge) is, in the feminine, “shofetet”; here, the infixed word structure of the masculine was not altered. The same suffixes are also used by the verbal system in the various tenses to denote the feminine gender, for example: The masculine verb-form “katav” (he wrote) becomes “katva” (she wrote) and the form “roked” (he dances) becomes “rokedet” (she dances). For a more detailed description of Hebrew morphology and word structure see Bentin & Frost, 1994.

Agreement rules exist; they are based on inflectional matching between words that carry inflection. They are the most fundamental tool for specifying syntactic relations in Hebrew sentences. 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 forms) 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: “Hashofet (article /Ha/ + subject; “the judge”) hahashdan (article /ha/ +
We chose to investigate the interaction between syntactic and other linguistic processes (lexical and semantics) using agreement rules, for two main reasons: (1) Agreement rules are a purely syntactic tool for indicating a functional relation between certain words. Thus by manipulating agreement rules, particularly between basic elements in sentences such as subject and predicate, we undoubtedly tap processes that are predominantly syntactic. (2) While the agreement rules are based on inflectional morphology, their violation does not induce changes in word class which may entail semantic implications (Carello, et al., 1988). Furthermore, because the information regarding the subject's number and gender is already available in the subject's form, violation of the agreement, does not affect the basic meaning of the sentence. Consequently, contextual effects observed using Hebrew agreement rules in a syntactic priming paradigm, may safely be related to syntactic rather than semantic processes.

In Experiment 1, we examined the role of lexical factors in syntactic priming using a target-probe match/mismatch decision paradigm. In Experiment 2, we examined the interaction between syntactic and semantic factors via a target-naming paradigm.

**EXPERIMENT 1**

In the strict modular view of syntactic processing, a word is first parsed into its lexical morpheme (i.e., its unmarked consonantal sequence) and its syntactic morphemes (such as its inflectional pattern). After parsing, the syntactic process is conjectured to be independent of other lexical information such as the word's semantic information. The present experiment was aimed at addressing this question of syntactic processing autonomy.

Targets, which were inflected words or pseudowords, were presented following a noun phrase containing a subject and its attribute (i.e., the target's context). Each word-target was a predicate that completed a three-word sentence; it could not be predicted on the basis of the semantic content of the context. Half of the words and half of the pseudowords were inflected for gender and number in agreement with the context, while the other targets were syntactically incongruent with the preceding context. The experimental subjects were instructed to match these targets to probes presented just before the context phrase. In our previous studies (e.g., Deutsch & Bentin, 1994), violation of agreement inhibited word-identification. Consequently, we predicted that RT for matching syntactically congruent words would be faster than syntactically incongruent words. Assuming that pseudowords are not represented in the lexicon, similar syntactic priming effects for words and pseudowords should support a modular view in which syntactic analysis is dependent only on the syntactic information in the stimulus.

**Method**

**Subjects.** The subjects were 72 undergraduate students who participated in this experiment as a course requirement. All of the subjects were native speakers of Hebrew and had normal or corrected vision.

**Stimuli and design.** Each stimulus item was a three word sentence which consisted of a noun phrase followed by a predicate, the target. The targets were 72 words and 72 pseudowords; each constituted the predicate in a three word sentence. For all the targets used in this study, inflection for the feminine gender and for plural number required the addition of a suffix to the unmarked form.

The pseudowords were constructed by substituting some of the consonants of a real word's root morpheme without changing the vowels or consonants of the syntactic word-pattern and without changing the inflectional morphemes. Hence, the global morpho-phonological structure of the pseudowords was identical to that of the word targets, except that these inflected phonological structures had no root meaning. In order to avoid phonemic ambiguity, all the targets were presented with the vowel points (Frost, 1994; Frost & Bentin, 1992).

The noun phrase (the context) preceding each target consisted of a noun subject and an attribute (e.g., "The pretty girl...".). The syntactic congruence between the target and its context was manipulated, forming two conditions. In the Congruent condition, the target agreed in gender and number with the syntactic structure of the context. In the Incongruent condition,
gender and number with the syntactic structure of the context. In the Incongruent condition, either the gender or the number or both the gender and the number of the target were different than those of the context, thus violating the rules of agreement.

In producing congruent stimuli, we avoided physical identity between inflections that agree (i.e., the two inflections were not the same letters or phonemes). This was done to avoid the confounding of syntactic congruence with rhyming or orthographic repetition effects. In doing so, we took advantage of the fact that different words may take different inflectional morphemes (suffixes) to denote a given gender. Thus, the subjects and attributes that were selected to form the context phrase were inflected by a different inflection than the one used for the same purpose in the target. Take, for example, the syntactically congruent sentence “Hayalda hayafa rokedet” (The pretty girl is dancing). The subject “yalda” (girl) and the attribute “yafa” (pretty) use the suffix /a/ to denote the feminine form but the predicate “rokedet” (is dancing) uses the suffix /et/ for the same purpose.

Half of the probes presented prior to the context were words and half were pseudowords. For each lexical category of the target (words or pseudowords), half of the trials were “match” trials, in which the target and the probe were identical, and half were “mismatch” trials in which the probe was different than the target. The probes used in the mismatch trials and their paired targets were different derivations of the same roots.

To summarize, there were 8 experimental conditions representing all combinations of three factors: a) lexicality (word, pseudoword), b) syntactic congruence (congruent, incongruent), and target-probe matching (match, mismatch). Each of the 72 target words and the 72 pseudowords were rotated across subjects to appear in each of the four possible combinations of syntactic congruence and matching. For example, in the following sentences the target word is mitragesh (“is anxious,” masc., sing.):

1. Word-congruent-match: probe mitragesh - “Harakdan hamefursam mitragesh” (The famous dancer is anxious).

The same context phrases were used for the target pseudoword mitkatzesh.

Hence, to complete this design, 576 sentences were needed, divided into 4 equal and balanced lists. A different group of 18 subjects was assigned to each list so that each subject was examined with 18 different targets in each condition and each target was presented in each condition to 18 subjects. Targets were rotated across subjects so that each target appeared with each context. Every experimental subject was presented with all conditions but received no repetitions of a given sentence.

Procedure. The experiment was conducted in a quiet and dimly lit room. The stimuli were presented on an MAC-SE computer using a standard Hebrew font. The same computer collected and timed key-press responses.

At the beginning of each trial a fixation mark was presented for 250 ms at the right end of the screen placed vertically one line above the middle of the screen. The fixation point was replaced by the probe such that the first letter of the probe replaced the fixation point. The probe remained on for 350 ms, and was followed by a 200 ms blank ISI. The context phrase was presented next for 700 ms. It was located one line under the (now absent) probe. A second ISI of 200 ms blank period separated the context from the target which was placed on the screen as a natural continuation of the line. The target was on the screen until the subject answered or up to 2 s. Two additional seconds separated one trial from the other.

The subjects were instructed to silently read the probe, and read the context aloud while waiting for the target. Their task was to press one button if the target and the probe were identical and another button if they were not. They were instructed to answer as fast as they
Results

Means and standard deviations of reaction time for correct responses were calculated for each subject in each experimental condition. Reaction times that were slower or faster than two standard deviations from the subject's mean in each condition have been excluded from the average. These outliers accounted for less than 5% of all responses.

For both match and mismatch trials, RTs were faster for syntactically congruent than for incongruent targets regardless of whether these were words or pseudowords. However, because the variance in the mismatch trials was high, we analyzed only trials on which the target matched the probe. These data are presented in Table 1.

The statistical significance of the apparent differences in RT was assessed by a CONGRUENCE (Congruent, Incongruent) x LEXICALITY (Words, Pseudowords) analysis of variance. A within-subjects design was used for the subjects analysis (F1) and a mixed-model design for items analysis (F2). These analyses showed that both main effects were significant. Correct match decisions were faster when the targets were syntactically congruent with the context (635 ms) than when they were incongruent (670 ms) [F1(1,69) = 18.14, MSe = 4959, p < 0.0001 and F2(1,140) = 5.06, MSe = 7723 p < 0.05], and word-targets (635 ms) were faster than pseudoword-targets (670 ms) [F1(1,69) = 17.84, MSe = 4783, p < 0.0001 and F2(1,140) = 14.24, MSe = 6574 p < 0.0001]. More importantly, the interaction between CONGRUENCE and LEXICALITY was not significant and its F-ratios were small [F1 (1,69) = 1.31, MSe = 7114, p > 0.2562; and F2(1,140) = 1.43, MSe = 7696, p > 0.2346].

The percentages of pseudoword errors (8.9%) and word errors (8.3%) were similar, F1(1,70) < 1.00. For both words and pseudowords, more errors occurred in the syntactically incongruent condition (10.15%) than in the congruent condition (6.94%), F1(1,70)= 11.45, MSe = 64.58, p < .001. As was the case with RT, the interaction between CONGRUENCE and LEXICALITY was not significant, F1(1,70) < 1.0.

Discussion

A syntactic congruency effect was found in the present experiment even though the match/mismatch task could have been successfully accomplished without any reference to the target's sentential context. Because the context was not visible when the probe was processed and it was irrelevant to the task, the syntactic priming effect is not likely to have been related to the match/mismatch decision. More plausibly, it reflects the context's influence on encoding the target when it appeared. Because the target was a natural continuation of the sentence, its processing was presumably integrated into the context. Notice, however, that the target could not have been predicted on the basis of the semantic context of the preceding phrase. Moreover, the gender-agreement rule did not have any semantic consequences. This integration probably included an accounting of the congruence between the inflectional morpheme in the target and the syntactic expectancies evoked by the context (see Deutsch & Bentin, 1994 for an elaboration of this priming mechanism).

Table 1. Mean reaction time in ms, and percentage of errors for words and pseudowords in the syntactical congruent and incongruent conditions.

<table>
<thead>
<tr>
<th>SYNTACTIC CONDITION</th>
<th>WORDS</th>
<th>PSEUDOWORDS</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>RT (SEM)</td>
<td>% ERRORS</td>
</tr>
<tr>
<td>INCONGRUENT</td>
<td>659 (18.6)</td>
<td>9.98 (1.10)</td>
</tr>
<tr>
<td>CONGRUENT</td>
<td>612 (18.8)</td>
<td>6.69 (1.09)</td>
</tr>
</tbody>
</table>

The most interesting result of the present experiment was, of course, the fact that significant syntactic priming was found for pseudowords as well as for words. Furthermore although the congruence effect was numerically bigger for words than for pseudowords, the interaction
The most interesting result of the present experiment was, of course, the fact that significant syntactic priming was found for pseudowords as well as for words. Furthermore although the congruence effect was numerically bigger for words than for pseudowords, the interaction between the two factors was not statistically significant. The syntactic congruence effect on processing the pseudowords, and the absence of the interaction between this effect and lexicality suggest that syntactic processes of inflectional agreement can proceed without a full analysis of the word’s lexical representation and, therefore, without the intervention of lexical semantic information.

The syntactic priming effect on pseudowords is particularly interesting given that, in the pseudoword condition, both the probe (that preceded the context phrase) and the target were pseudowords. Hence, having the probe, the subject knew that the target was also going to be a pseudoword. Apparently, despite this knowledge, experimental subjects did not inhibit either their processing of the inflection or their formation of syntactically based expectations; they analyzed the inflection in the inflected pseudoword vis-à-vis the sentential syntactic structure. This outcome supports the hypothesis of an autonomous syntactic processor.

Although there was no significant interaction between lexicality and syntactic congruence, the numerical difference in the size of the syntactic priming effect between the word condition and the pseudoword condition weakens support for the autonomy hypothesis and suggests, instead, that the syntactic process may not be completely independent from lexical semantic information. This suggestion was followed up in Experiment 2.

**EXPERIMENT 2**

As Experiment 1 suggested, although an inflectional analysis of the stimulus occurred whether it did or did not have a lexical entry (i.e., a semantic sense), the process of analysis may, nevertheless, be modulated by lexical-semantic factors.

It is usually difficult to disentangle semantic from purely grammatical aspects of syntactic information. However, the gender-agreement rule in Hebrew provides one such approach. As previously mentioned, all the nouns in Hebrew (animate and inanimate) are marked for gender, either masculine or feminine. Within animate word pairs, the masculine is typically the unmarked form and the feminine gender the marked. The same inflectional markers used for animate feminine nouns (the suffixes described above) are used to mark the feminine for inanimate subjects. This consistency provides the experimenter with a way of distinguishing between the purely syntactic use of gender (i.e., for inanimate nouns which can have no sexual gender) and a syntactic-plus-semantic use of gender (i.e., for animate nouns). Thus, because the same inflectional markers are used to denote both grammatical and real gender, manipulation of the congruency of gender inflections may affect both grammatical and semantic/pragmatic processes for animate nouns, but only grammatical processes for inanimate nouns. Consequently, differences in the effects of manipulating the subject-predicate gender-agreement rule for inanimate versus animate subjects may reflect the difference in processing syntax which has only formal syntactic consequences (e.g., agreement) versus processing syntax which has, in addition, semantic consequences (e.g., sexual gender). If the syntactic processes that entail the analysis of agreement are influenced by semantic factors, the interference caused by violation of the gender agreement may have a stronger effect for animate than for inanimate nouns.

Because in the present experiment all the target items were words, we were able to avoid certain complications caused by the decision task that was used Experiment 1. In Experiment 1, RT speed may have been affected by nuisance factors related to the decision itself (i.e., the decision same vs. different). In the present experiment we avoided that potential problem by using a naming task.

Although naming might involve only pre-lexical phonological computation, and therefore, in principle, need not be sensitive to higher-level linguistic processes, recent models and data on naming in shallow languages such as Serbo-Croatian (Carello, Turvey, & Lukatela, 1992; 1994) as well as in deep languages such as English (McCaan & Besner, 1987) and Hebrew (Frost, 1995) have demonstrated that lexical information shapes the pre-lexical computation in a top-down manner. Moreover, when the orthographic pattern of the word is very familiar or when the
lexicon directly (for a recent discussion of this alternative option in naming, see Bentin & Ibrahim, in press). In order to encourage direct lexical access, all the stimuli in the present experiment were typed in unpointed Hebrew letters.

Method

Subjects. The subjects were 48 undergraduate students who did not participate in the first experiment. 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 word-targets that were the predicates concluding three-word sentences. Each target was embedded in four different sentential contexts, one of the four different combinations of a $2 \times 2$ design: ANIMACY (Animate, Inanimate) $\times$ SYNTACTIC CONGRUENCY (Congruent, Incongruent). In animate contexts the subject of the sentence was an animate noun. In inanimate contexts, the subject of the sentence was an inanimate noun. Half of the noun subjects in each animacy condition were masculine gender and half were feminine. Each noun subject was followed by a congruently inflected attribute. The syntactic congruence between the target (predicate) and its sentential context was manipulated within each animacy condition, forming two levels of the SYNTACTIC CONGRUENCE factor. In the Congruent condition the target was inflected to agree in gender with the subject and attribute. In the Incongruent condition the inflection of the target did not agree in gender with the context. Take, for example, the target “nafal” (fell down). The four different trial types in which this target was used were:

1. Animate-congruent: “The suspicious judge fell down” which is, in Hebrew, “Hashofet (sub., masc.) haxshdan (attrib., masc.) nafal (pred., masc.).”
2. Animate-incongruent: “Hashofet (fem.) haxshdanit (fem.) nafal (masc.).”
3. Inanimate-congruent: “The shiny fork fell down” which, in Hebrew, is: “Hamazleg (sub., masc.) hanozez (attrib., masc.) nafal (pred., masc.).”
4. Inanimate-incongruent: “The shiny spoon fell down”: “Hakapit (sub., fem.) hanocezet (attrib., fem.) nafal (pred., masc.).”

As in the previous experiment, phonetic priming was avoided by using subjects and attributes that take different inflectional morphemes to denote the feminine gender that taken by the target.

The resulting 192 sentences (48 targets presented in four context conditions) were divided into 4 stimuli lists. Each list included 48 different sentences, 12 in each of the four animacy/congruence conditions. Twelve 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 two-factorial within-subject ANOVA with both subjects and items as random factors.

Procedure. The sentential context appeared on the center of the screen for 2000 ms, followed by the target word which appeared as a continuation of the sentence. The target remained on the screen for 1000 ms. RTs were measured from the onset of the target until the onset of naming. Subjects were asked to read aloud the context as well as the targets, but speeded performance was required only for the targets. 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 for each subject and separately for each target in each of the conditions. Outliers of more than two standard deviations accounted for less than 0.5% of the responses and were excluded from the recalculated averages.

For both animate and inanimate context, congruent predicates were named equally fast. Syntactic incongruence led to slower responses. Importantly, the congruency effect was three times as large in the animate than in the inanimate condition (Table 2).
Table 2. Mean reaction time in ms and SEM, in parentheses, for targets in the syntactically congruent and incongruent context, for animate and inanimate conditions.

<table>
<thead>
<tr>
<th>CONGRUENCY CONDITION</th>
<th>ANIMACY CONDITION</th>
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<tbody>
<tr>
<td></td>
<td>ANIMATE</td>
<td>INANIMATE</td>
</tr>
<tr>
<td>INCONGRUENT</td>
<td>560 (11.9)</td>
<td>538 (10.3)</td>
</tr>
<tr>
<td>CONGRUENT</td>
<td>528 (10.8)</td>
<td>528 (9.3)</td>
</tr>
<tr>
<td>CONGRUENCY EFFECT</td>
<td>32 ms</td>
<td>10 ms</td>
</tr>
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</table>

ANOVA showed that the syntactic congruency effect was statistically reliable by both subjects \([F(1,47)=16.33, \text{MSE} = 1311, p < .0001]\) and items analyses \([F2(1,47) = 3.68, \text{MSE} = 868, p < .0001]\). The interaction was significant for subjects \([F1(1,47)=6.43, \text{MSE} = 925, p < .025]\), but not for items \([F1(1,47) = 2.54, \text{MSE} = 1994, p < .12]\). Post-hoc comparisons on subject means revealed that while the syntactic congruency effect was significant for animate condition \([t(47)= 18.73, p < 0.001]\), it was not reliable for the inanimate condition \([t(47)= 2.65, p > 0.11]\). Moreover, a planned t-test revealed that the 32 ms congruency effect for the animate targets was significantly bigger than the 10 ms congruency effect for the inanimate targets, both for the subjects \([t(47)=1.48, p<0.0001]\) and items analyses \([t(47)=2.38, p < 0.025]\). The 10 ms congruency effect for inanimate nouns was not significant.

Discussion

The most important outcome of the present experiment was that the syntactic priming effect was significantly bigger when the subject of the sentence was animate than when the sentence had an inanimate subject. Because syntactic priming in the present experiment was related to the agreement or disagreement in gender between the predicate and the preceding noun-phrase denoting the subject of the sentence, it is evident that the interaction between the syntactic congruency effect and the animacy of the subject reflected the difference in the role of gender for animate and inanimate sentence-subjects. Apparently, readers are more disturbed by violation of gender-agreement when the gender has a semantic/pragmatic value than when it denotes an arbitrary, pure syntactic agreement. The sensitivity of the syntactic process to the semantic meaning may indicate that the inflectional processor is exposed to semantic information of the word, and not just to its grammatical characteristics.

Before concluding this section two caveats should be considered. One is the possibility that all the observed priming effect is explained by semantic rather than syntactic factors. Such a suspicion might be elicited, for example, by previous studies in which syntactic priming was found in lexical decision but not in naming (Carello et al., 1988; Seidenberg et al., 1984; Sereno, 1991) or in which, relative to lexical decision, syntactic priming in naming was significantly attenuated (West & Stanovich, 1986). However, it is unlikely that semantic factors solely accounted for the present priming effect. This claim is supported primarily by the fact that the same predicates (targets), were used with both animate and inanimate targets. Therefore the semantic relationships within the sentences in both conditions were very similar and should have produced equal effects. Moreover, none of the targets was semantically or associatively related to the preceding words in the context or could have been predicted on the basis of the sentence semantic context. In addition, it is logically necessary to process the inflectional incongruence between the subject and the predicate in order to experience any semantic incongruence.

The second caveat is that, relative to the animate group of nouns, the inflectional system for the group of inanimate nouns is less regular; in this group there are more exceptions in which a masculine noun takes a feminine plural suffix (and vice versa). It is possible, therefore, that the difference observed between the animate and inanimate conditions stemmed from an effect of ambiguity (i.e., predictability) due to their difference in inflectional consistency. Experiment 3 was designed to control for this possibility.
EXPERIMENT 3

The irregularity of the inflectional system associated with the gender of inanimate nouns is particularly conspicuous in plural form. As mentioned above, two suffixes in Hebrew are used to denote a plural: one that is regularly used for masculine /im/ and one regularly used for feminine /ot/. However, whereas for words denoting animate concepts this rule is almost always true, for inanimate concepts there are irregular cases. Most of these cases are masculine nouns that take the /ot/ suffix to denote the plural form (and use masculine inflections for their predicates), but there are also a few in which feminine nouns accept the /im/ suffix to denote the plural form. Thus, although for inanimate nouns there is a correlation between the inflectional structure of a word and its grammatical gender, their inflectional structure coincides with their gender less regularly than it does for animate nouns. Accordingly, the native speaker of the language may be less disturbed by gender disagreement in inanimate nouns because the inflectional system is less regular than for animate nouns.

In order to examine the effect of inflectional regularity on the syntactic priming effect, in the present experiment we compared this effect for “regular” and “irregular” nouns. As in the previous experiments syntactic priming was induced by violating the gender subject-predicate agreement, while manipulating gender-regularity in inanimate nouns. If the difference between the syntactic priming effect for animate and inanimate subjects reflected mainly the difference between processing inflectional regular and irregular word categories, a smaller syntactic priming effect should be found for irregular than for regular forms.

Method

Subjects. The subjects were 48 undergraduates students, who did not participate in any of the two previous experiments. They were all native speakers of Hebrew, who took part in the experiment for course credit or payment.

Stimuli and design. In the present experiment we used 48 target words. Because, as described in the introduction, most irregular nouns are masculine, we could not manipulate the agreement between the subject and the predicate by changing the noun phrase (context) while keeping the predicate (target) intact. Therefore, unlike in the previous experiments, the masculine form of the target was used in the congruent condition while its feminine form was used in the incongruent condition. The same target was used, however, within congruity conditions for both regular and irregular nouns. Take for example the target “fell down” which in the masculine form sounds “nafal” whereas in the feminine forms sounds “nafal.” This target was used in conjunction with the regular masculine noun yahalom/ (dimond) (in plural form yahalomim), and with the irregular masculine noun /mazleg/ (fork) (in plural form mazlegot) to form the following 4 experimental conditions:

1. Regular-congruent: “Hayahalom (sub. masc.) hanotzez (attrib. masc.) nafal (pred. masc.)” - (The shining diamond fell down).
2. Regular-incongruent: “Hayahalom (masc.) hanotzetz (masc.)nafala (fem.).”
3. Irregular-congruent: “Hamazleg (sub. masc.) hanotzez (attrib. masc.) nafal (pred. masc.)” - (The shiny fork fell down).
4. Irregular-incongruent: “Hamazleg (masc.) hanotzetz (masc.) nafala (feminine).”

Each subject was examined in all four conditions, using different targets in each condition. This design allowed a within subject (F1) and within item (F2) ANOVA design with REGULARITY (regular, irregular) and SYNTACTIC CONGRUITY (congruent, incongruent) as main effects.

Procedure. Experimental procedure of Experiment 3 was identical to this of Experiment 2.

Results

As in the previous experiment, responses that were shorter than 150 ms (less than 4% of the responses) and outliers of more than 2 Sds (less than 3%) were excluded. For sentences having an irregular noun subject as well as for sentences with a regular subject, syntactically congruent targets were named faster than syntactically incongruent targets (Table 3).
Table 3. Mean reaction time in ms and SEM, in parentheses, for regular and irregular inanimate targets in the syntactically congruent and incongruent context.

<table>
<thead>
<tr>
<th>CONGRUENCY CONDITION</th>
<th>REGULARITY CONDITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REGULAR</td>
</tr>
<tr>
<td>INCONGRUENT</td>
<td>632 (12.1)</td>
</tr>
<tr>
<td>CONGRUENT</td>
<td>599 (13.0)</td>
</tr>
<tr>
<td>CONGRUENCY EFFECT</td>
<td>33 ms</td>
</tr>
</tbody>
</table>

ANOVA corroborated these observations showing a significant syntactic congruity effect \([F(1,47) = 22.94, MSe = 2036, p < 0.001, F(1,47) = 18.06, MSe = 2887, p < 0.001]\), and no significant effect of regularity \([F(1,47) = 1.54, MSe = 1709, F(1,47) < 1.0]\). Most importantly, as revealed by a non-significant interaction \([F(1,47) < 1.0, F(1,47) < 1.0]\), the syntactic congruity effect was similar for regular and irregular subject nouns.

Discussion

The similarity of the syntactic priming effect induced by the violation of subject-predicate agreement for regular and irregular nouns suggests that the syntactic priming effect is not influenced by the inflectional transparency of the noun gender classification. That is, the difference between animate and inanimate nouns in sensitivity to agreement in gender was not due to the existence of greater inflectional inconsistency in the inanimate group. Hence, these results help rule out the concern that the difference between the syntactic priming effects observed for animate and inanimate nouns was mediated by inflectional rather than semantic factors. At the same time, however, the magnitude of the syntactic priming effect for inanimate noun phrase contexts contrasts with the pattern of results in Experiment 2 and may be in conflict with their interpretation.

In Experiment 2 we have found a very small (and statistically unreliable) syntactic priming effects for inanimate nouns. In contrast, in the present experiment the magnitude of the syntactic priming effect was bigger, in fact, as big as the syntactic priming effect in for animate noun phrases in Experiment 2. There are several possible explanations for this difference. One stems from the fact that in Experiment 3, unlike in the previous experiments, all congruent targets were masculine (i.e., not inflected) while all incongruent targets were feminine (i.e., inflected). Therefore, the syntactic congruence effect was confounded (al least in part) with simple inflectional, or even phonetic effects because the feminine-inflected targets were more complex and longer than the masculine targets. It is well known that naming time is positively correlated with the length of the word (Frederiksen & Kroll, 1976).

To assess the hypothesis that feminine nouns take longer to name because they are longer in length, we ran a separate group of subjects in a task of naming each stimulus in isolation using the specific stimuli used in Experiment 2. Although there was a difference in the expected direction (masculine nouns averaged 506 ms and feminine nouns 510 ms), the difference was small and not significant.

A second possible explanation is that the processing difference found between sentences with animate or inanimate subjects was strategic: induced, in Experiment 2, by mixing the two noun categories (every experimental subject received both kinds of stimuli). It is possible that this mixture sensitized the subject to the difference between these two categories thereby affecting sentence processing strategies. Additional research is necessary to examine these explanations.

GENERAL DISCUSSION

In the present study we examined the independence of the relationship between syntactic processes based on Hebrew inflectional morphology, and lexical and semantic factors. In three experiments, we manipulated the gender agreement between the noun phrase and the predicate in three-word sentences. This manipulation induced a syntactic priming effect reflected by a faster processing of syntactically congruent than of syntactically incongruent targets.
In Experiment 1 we found that the magnitude of this syntactic priming effect was similar for word and pseudoword targets. This pattern suggests that syntactic processes based on inflectional morphology are automatically applied to all phonologically legal structures, regardless of whether they are or they are not represented in the lexicon. In this respect, the present results are similar to those found when inflectional morphology of case agreement between adjective and noun was manipulated in Serbo-Croatian (Katz et al., 1987). Using a lexical decision task with spoken stimuli these authors found an equivalent syntactic priming effect when the prime was a meaningless pseudoadjective as well as when it was real adjective. However, the results of Experiment 2 suggested that syntactic processing is not indifferent to the semantic characteristics of the target. In that experiment we have found that disagreement in gender between the predicate target and the preceding noun phrase delayed naming the target significantly more if the subject of the sentence was an animal or a human being (i.e., a word whose grammatical gender correlated with one of its semantic/pragmatic values) than if the subject was inanimate, (i.e., a word whose grammatical gender had only grammatical value). The result that naming in the animate incongruent condition was slower than the other three conditions (which were all equal among themselves) suggests that the effect was inhibitory.

Finally, the results of Experiment 3 showed that the difference in syntactic priming for sentences including animate and inanimate subjects was not accounted for by the relatively higher percentage of irregular inflection for gender in the inanimate than in the animate nouns.

The syntactic priming effect on processing inflected pseudowords suggests that the inflectional analysis of phonological stimuli (on which the syntactic processor could have operated), does not require full activation of a specific lexical entry. In other words, when the reader is exposed to an orthographic representation of an inflected phonological unit, inflectional analysis of the stimulus is initiated to identify its grammatical characteristics. The initiation (and probably the successful completion) of this process probably does not depend on the successful completion of lexical access or semantic identification. Such a description would be in accord with the inflectional decomposition conception of lexical organization, by which a connection is established between inflectional base unit and the various inflectional affixes with which it usually combines in the language (Marslen-Wilson, Tyler, Waksler, & Older, 1994).

This is not to say, however, that the syntactic process is completely independent of the lexical status of a stimulus (i.e., word or pseudoword) and, if the stimulus is a word, its semantics. The results of Experiment 1, although not significant, hinted at a stronger congruity effect for words than for pseudowords, a trend we have found repeated in several unpublished experiments in our laboratory. The animacy manipulation in Experiment 2 provided more direct support for an interaction between syntactic, lexical, and semantic cognitive information. Since the animacy value of a word is an fundamental part of a word's semantic characteristics, the influence of this factor on syntactic priming indicates that the syntactic processing of inflectional morphology is sensitive to lexical and semantic processes.

Semantic information may, for example, support the processing of a sentence in relatively late stages of sentence integration. This interpretation is supported by the asymmetrical effect of animacy on the congruent and incongruent conditions. If animacy would have had affected the process of identifying the grammatical characteristics of the word, the difference between the animate and the inanimate conditions would have been observed in both the congruent and the incongruent condition. However, naming of congruent predicates was equivalent for animate and inanimate noun subjects.

On the other hand, the effect of animacy can not be so late as to be irrelevant to word recognition because the interaction between animacy and syntactic congruence occurred for a process that is considered to be relatively shallow: naming. Naming is considered to require minimal contact with the lexicon as opposed to "deeper" tasks like lexical decision. The interaction result is consistent with previous studies in which syntactic congruence affected word identification, and supports our previous suggestion that syntactic priming and its interaction with semantic information occurs at a relatively low level of processing (Deutsch & Bentin, 1994). We conjecture that the process of word identification is supported in parallel by many levels of linguistic analysis, phonological, inflectional and semantic.
In summary, the above interpretation may fit into an interactive model of linguistic system where various processes associated with various aspects of the linguistic input may operate independently. However, possible mutual connection between these processes may facilitate or inhibit each of this processes or the operation of the whole system as a unit.

REFERENCES


**FOOTNOTES**

1 Hebrew University, Jerusalem
2 Also Hebrew University, Jerusalem.
3 Also University of Connecticut, Storrs.

1 The minimal attachment principle postulates that the initially preferred syntactic parsing is the one which entails the minimal number of syntactic nodes. Accordingly, the initial parsing of a sentence that includes a prepositional attachment ambiguity will be of a simple active sentence in which the prepositional phrase will be attached to the main verb phrase. For example in the sentence "The spy saw the cop with a revolver." the prepositional phrase "with a revolver" will be initially attached to the main verb phrase "saw" rather than to the preceding noun phrase "the cop."

2 Except for few cases of specific nominal sentences.

3 Another agreement rule requires that the subject and attribute will agree in gender, number and definity. Accordingly, in the above example, the form of the attribute ("haxashdan") has also changed ("haxashdanit") when the masculine subject noun phrase had been replaced by a feminine noun.

4 Hebrew is written from right to left.

5 For example, the inanimate noun "knisa" (an entrance) uses the suffix "a" to denote its feminine gender like it is used to change the masculine "ydEd" (a boy) into the feminine "yalda."