

When zebras become painted donkeys: Grammatical gender and semantic priming interact during picture integration in a spoken Spanish sentence

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This study investigates the contribution of grammatical gender to integrating depicted nouns into sentences during on-line comprehension, and whether semantic congruity and gender agreement interact using two tasks: naming and semantic judgement of pictures. Native Spanish speakers comprehended spoken Spanish sentences with an embedded line drawing, which replaced a noun that either made sense or not with the preceding sentence context and either matched or mismatched the gender of the preceding article. In Experiment 1a (picture naming) slower naming times were found for gender mismatching pictures than matches, as well as for semantically incongruous pictures than congruous ones. In addition, the effects of gender agreement and semantic congruity interacted; specifically, pictures that were both semantically incongruous and gender mismatching were named slowest, but not as slow as if adding independent delays from both violations. Compared with a neutral baseline, with pictures embedded in simple command sentences like “Now please say ____”, both facilitative and inhibitory effects were observed. Experiment 1b replicated these results with low-cloze gender-neutral sentences, more similar in structure and processing demands to the experimental sentences. In Experiment 2, participants judged a picture’s semantic fit within a sentence by button-press; gender agreement and semantic congruity again interacted, with gender agreement having an effect on congruous but not incongruous pictures. Two distinct effects of gender are hypothesised: a “global” predictive effect (observed with and without overt noun production), and a “local” inhibitory effect (observed only with production of gender-discordant nouns).

INTRODUCTION

Grammatical gender is observed in over half of the world’s languages, but its role in sentence processing is still poorly understood. To produce or comprehend a sentence properly, speakers of gender-marked languages must maintain agreement between words at various levels, from morphological agreement between gender-marked articles and nouns (e.g., *una escoba*) to discourse-level agreement between gender-marked pronouns and the nouns to which they refer. Hence, grammatical gender has recently gained popularity in psycholinguistic and neurolinguistic research, both as an interesting phenomenon in its own right and as a useful tool for analysing real time language processes at various levels and time points. The focus of the current study is to determine if grammatical gender agreement in Spanish can elicit facilitative or inhibitory priming for a picture during on-line sentence comprehension, in two tasks, picture naming and semantic judgement, and if so, whether or not syntactic level priming can interact with semantic level context effects.

Researchers have used the gender of nouns to investigate word retrieval and word production (e.g., Akhutina, Kurgansky, Polinsky, & Bates, 1999; Bates, Devescovi, Hernandez, & Pizzamiglio, 1996; Bates, Devescovi, Pizzamiglio, Damico, & Hernandez, 1995; Bentrovato, Devescovi,

D'Amico, & Bates, 1999; Bentrovato, Devescovi, D'Amico, Wicha, & Bates, 2003; Grosjean, Dommergues, Cornu, & Guillelmon, 1994; Jacobsen, 1999; van Berkum, 1997; Vigliocco & Franck, 1999; Vigliocco, Lauer, Damian, & Levelt, 2002; Vigliocco, Vinson, Indefrey, Levelt, & Hellwig, 2004; Vigliocco & Zilli, 1999), cohort activation in word recognition (e.g., Dahan, Swingley, Tanenhaus, & Magnuson, 2000), processing differences between pictures and words (e.g., Bowers, Vigliocco, Stadthagen-Gonzalez, & Vinson, 1999), the relative timing of syntactic and phonological processes during lexical access (e.g., Schmitt, Rodriguez-Fornells, Kutas, & Munte, 2001a; Schmitt, Schiltz, Zaake, Kutas, & Munte, 2001b; van Turennout, Hagoort, & Brown, 1998) and the interplay between discourse, semantic, and syntactic level processes (e.g., Brown, van Berkum, & Hagoort, 2000; Deutsch & Bentin, 2001; Deutsch, Bentin, & Katz, 1999; Gunter, Friederici, & Schriefers, 2000; Gunter, Stowe, & Mulder, 1997; Hagoort, 2003; van Berkum, Brown, & Hagoort, 1999; Wicha, 2002; Wicha, Bates, Moreno, & Kutas, 2000). Recent studies have also provided electrophysiological evidence for the brain's sensitivity to gender agreement during sentence comprehension (e.g., Brown et al., 2000; Demestre, Meltzer, Garcia-Albea, & Vigil, 1999; Deutsch & Bentin, 2001; Gunter et al., 2000; Hagoort, 2003; Hagoort & Brown, 1999; van Berkum et al., 1999; Wicha, Bates, Moreno, & Kutas, 2003; Wicha, Moreno, & Kutas, 2003; Wicha, Moreno, & Kutas, 2004). Most relevant to the current study are findings from several languages showing that grammatical gender can also contribute to lexical processing, by "priming" the recognition and/or retrieval of an upcoming word and eliciting facilitation (from an agreeing noun or modifier) or inhibition (from a discordant noun or modifier) relative to some baseline.

The type of priming, whether facilitative or inhibitory, that syntactic level cues like gender can elicit is a matter of some debate. Several studies have analysed both semantic (e.g., Duffy, Henderson, & Morris, 1989; O'Seaghdha, 1989, 1997; Simpson, Peterson, Casteel, & Burgess, 1989; Williams, 1988) and syntactic (e.g., West & Stanovich, 1986) level context effects, generally concluding that syntactic primes lead mainly to inhibition but no facilitation, because they affect processes that occur after word access, whereas semantic priming is mainly facilitative, caused by lexical level word associations—e.g., dog primes cat, because they are associated words in the lexicon or co-occur frequently in the language (see Lucas, 1999; O'Seaghdha, 1997). In agreement with these studies, gender priming that leads to inhibitory syntactic effects has been reported in Italian using auditory gender monitoring (also called gender classification; Bates et al., 1996) and in German using visual lexical decision (Friederici & Schriefers, 1994; Schriefers, Friederici, & Rose, 1998) and cross-modal visual word naming (Friederici, Garrett, & Jacobsen, 1999 for an overview of the

effects of gender in comprehension and production tasks; Jacobsen, 1999; see Schriefers & Jescheniak, 1999). In all cases, response times were slower for words that were preceded by mismatching gender information, relative to some baseline. However, several studies have also reported facilitative priming effects of gender. For example, gender facilitation was observed for word pairs in French using gating and auditory lexical decision (Grosjean et al., 1994) and in Italian (Bates et al., 1996) and Russian (Akhutina et al., 1999) using cued shadowing. In these studies, the gender of a word facilitated its retrieval relative to words that provided no gender information. Gender agreement has also shown facilitation for picture naming times in Italian (Bentrovato et al., 1999) and German (Hillert & Bates, 1996; Jacobsen, 1999) sentences, where pictures that were consistent with the gender of a preceding modifier were named faster than the same pictures in a neutral context. In regard to the potential interaction between gender and sentential context, on one hand, some researchers analysing semantic and syntactic features simultaneously within a sentence context have concluded that the two context effects are isolatable and independent (e.g., Gunter et al., 1997, 2000; O'Seaghdha, 1997), and on the other hand, at both semantic and syntactic levels, several studies have provided examples of anticipatory context effects that can interact in the course of sentence processing (e.g., Bentrovato et al., 1999; Brown et al., 2000; Federmeier & Bates, 1997; Van Petten, 1993; Van Petten & Kutas, 1991a).

The question herein is whether morpho-syntactic information, specifically grammatical gender, can elicit facilitative and/or inhibitory priming for picture names in a sentence context, and whether it interacts with sentential priming effects during semantic integration of a picture. If so, is the effect the same across tasks that require overt naming and those that do not? Experiment 1a investigates the effects of gender agreement and semantic congruity on naming times in an on-line picture-naming task. Experiment 1b explores an alternative neutral linguistic baseline, to test the robustness of the effects in Experiment 1a. Experiment 2 explores the effects of the same gender and sentential factors in a semantic judgement task, wherein overt production of the picture's name is not required.

EXPERIMENT 1A: GENDER AGREEMENT AND SEMANTIC PRIMING EFFECTS ON PICTURE-NAMING TIMES

In Experiment 1a, participants performed a cross-modal picture-naming task using spoken sentences in Spanish with an embedded line drawing. We chose picture-naming times as the primary dependent measure, since they are sensitive to a variety of syntactic and semantic priming effects (e.g., Bentrovato et al., 1999; Bock & Levelt, 1994; Federmeier & Bates,

1997; Glaser, 1992; Hillert & Bates, 1996; Jacobsen, 1999; Levelt, 1992; Levelt, Roelofs, & Meyer, 1999; Potter, 1986; Potter & Faulconer, 1975). Picture naming has been successfully used to demonstrate sentential facilitation of lexical access in English (Roe et al., 2000), syntactic priming in English (Federmeier & Bates, 1997) and Chinese (Lu et al., 2000), and gender facilitation effects in Italian (Bentrovato et al., 1999) and German (Hillert & Bates, 1996; Jacobsen, 1999). Another advantage of using pictures is that the same materials could be used to assess context effects in a task with no explicit word production.

In Experiment 1a, two variables were manipulated in a factorial design: (1) gender agreement between the target noun and the determiner immediately preceding it and (2) semantic congruity of the picture target within the sentence context. An additional set of simple-command sentences with the same embedded pictures was used as a baseline comparison. The specific goals of Experiment 1a were three-fold; first, to determine if gender and/or semantic congruity affect naming of a picture target during on-line sentence comprehension; second, if so, whether their effects are additive or interactive; and third, whether or not gender agreement elicits facilitative and/or inhibitory priming effects relative to a neutral baseline.

Method

Cloze-Probability Procedure. Cloze probability is a measure of response consensus for a specific lexical item given a particular sentential context, where a high-probability (high cloze) target creates a good and likely continuation of the sentence. To obtain a set of experimental sentences with the highest cloze noun for each, 128 sentences were cropped at the target noun and presented to participants in one of three lists: (1) with no target article, (2) with a feminine article, or (3) a masculine article, for example, *Siempre que voy a barrer el piso con la / el / ø ___* —“Whenever I’m going to sweep the floor with the[fem] / the[masc] / ø ___”. The feminine or masculine articles were considered appropriate or inappropriate for each sentence, based on how the experimenter had written the complete sentences (i.e., “broom” was the target in the example above, so *la escoba* was appropriate and *el* inappropriate). Paid participants, 60 (22 male; 38 female; mean age 22.3 years, range 18–42) native Spanish speakers, completed the sentences by writing in the first noun (or article and noun) that came to mind, or an “X” if they found no plausible answer. Participants were randomly assigned to one of three gender conditions (appropriate, inappropriate and no article) for a total of 20 participants per list; they did not participate in further experiments.

The highest occurring word was determined for each sentence, and then the average percent agreement (number of participants providing that

same response divided by the total number of responses for each sentence) was determined for each item. These norming scores were subjected to one-way analyses of variance over items, showing a significant difference in cloze across the three conditions, $F_2(2, 381) = 120.47, p < .0001$. All pairwise comparisons were significant at $p < .0001$ after Bonferroni/Dunn correction, showing highest cloze for gender-appropriate articles, then no articles, then inappropriate articles, confirming the strength of the sentential contexts and the gender agreement manipulation at the article. Sentence pairs for Experiments 1 and 2 were derived from the 110 highest cloze items in the no-article sentence condition, using the dominant article and noun (mean cloze 0.68 at article and 0.81 at noun).

Materials. Stimuli consisted of 110 pairs of spoken Spanish sentences (i.e., prerecorded auditory presentation), with an embedded picture that replaced a critical noun and was always preceded by a gender-marked article. The picture target could either fit the semantic context or not, and either matched in gender with the preceding article or not, creating four experimental conditions: (1) gender matching—semantically congruous, (2) gender matching—semantically incongruous, (3) gender mismatching—semantically congruous, and (4) gender mismatching—semantically incongruous. The picture could appear anywhere in either the first or second sentence, but was never sentence-final. A fifth condition, used as the neutral baseline, was created with a set of simple command sentences (e.g., “Now please say . . .”) with no article preceding the picture target, such that any picture could fit semantically when embedded in these gender-neutral sentences, eliciting a simple cued-naming response. The following are examples sentences (Spanish with English gloss) with picture targets in BOLD.

Gender Matching: semantically congruous and incongruous targets

*Siempre que voy a barrer el piso con la **ESCOBA** / **VELA** traigo el recogedor. Por eso siempre los guardo en el mismo armario.*

Whenever I'm going to sweep the floor with the_[fem] **BROOM**_[fem] / **CANDLE**_[fem] I bring the dustpan. That is why I always store them in the same closet.

Gender Mismatching: semantically congruous and incongruous targets

*Siempre que voy a barrer el piso con el **ESCOBA** / **VELA** traigo el recogedor. Por eso siempre los guardo en el mismo armario.*

Whenever I'm going to sweep the floor with the_[masc] **BROOM**_[fem] / **CANDLE**_[fem] I bring the dustpan. That is why I always store them in the same closet.

Simple Cued Naming: Neutral Baseline*Ahora por favor nombre ESCOBA / VELA*Now please name **BROOM**_[fem] / **CANDLE**_[fem]

Two black-on-white line drawings (300 × 300 dpi) were assigned to each sentence; one sensible and one non-sensible continuation. The picture referents were matched on grammatical gender, and as closely as possible on number of syllables (mean 2.7 syllables; range 1–4 syllables) and word frequency (Juilland & Chang-Rodriguez, 1964). The pictures had 0.90 mean naming agreement (range ~0.50–1) out of context as per Bates et al. (2000). In addition, every picture appeared once in each condition to avoid lexical influences (e.g., frequency) for any one condition disproportionately. Overall, there were 54 masculine and 56 feminine picture targets. All targets were imageable nouns compiled from various published studies and databases—e.g., Abbate and LaChapelle (1984a, 1984b), Dunn and Dunn (1981) and Snodgrass and Vanderwart (1980); see Bates et al. (2000, 2003)—representing mostly inanimate objects, as well as 22 pictures of animals with same grammatical gender across sexes (e.g., *pingüino*—penguin; except for dog = *perro/perra* and bear = *oso/osa*; both more frequent in masculine form in Spanish) and 1 gender-ambiguous picture of a clown face. Six items were plural (socks, eggs, peanuts, scissors, flies, and eyes).

The sentences were recorded using a DAT recording device in a soundproof chamber, transferred to a Macintosh computer as individual SoundEdit 1.0 files, cleaned (blank spaces removed before and after the utterance) and a time-lock marker placed before the target, then converted into individual PsyScope files (Cohen, MacWhinney, Flatt, & Provost, 1993) for experimental presentation. Each sentence was recorded twice, spoken in a normal conversational intonation by a male, native speaker of Spanish. One version contained a definite (i.e., the = *el, la, los, las*) or indefinite article (i.e., a/an = *un, una*) with the gender of the highest cloze noun (e.g., *la escoba*—the[fem] broom), the other contained an article of the opposite gender (e.g., *el*—the[masc]). Mean article duration was 346 ms, with a range from 198–85 ms. The reader was not provided with the target noun, hence recording each sentence with a silence after the critical article. The appropriate picture was called into this space during on-line presentation. The context preceding the target article and drawing varied in length (mean: 3,254 ms, range: 1,464–10,132ms; mean 16.3 words, range 6–30) and in number of articles (mean 1.7, range 0–5), thus decreasing the predictability of the target's sentence position.

The average cloze probability at the article for the experimental sentences (i.e., the no-article condition in the cloze procedure) was 0.68 (+/– 0.2; range 0.25–1). The cloze for the same sentences at the noun

following the “expected” article (i.e., the correct-article condition) was 0.81 (+/- 0.1; range 0.40–1), and following the article of opposite gender (i.e., the incorrect article condition) was 0.35 (+/- 0.2; range 0.10–0.95). The semantically congruous pictures were depictions of the highest cloze noun for each sentence from the no-article condition.

The sentences were distributed across five lists such that each list had the same number of sentences per condition, and each sentence pair and picture target appeared only once per list. To do this given that the sentences were paired with counterparts, the gender matching—semantically incongruous condition for each sentence and the gender mismatching—semantically congruous condition of its counter-sentence always appeared in the same list. The other three conditions were then randomly assigned to the remaining three lists.

Participants. A group of 36 (21 males; 15 females) right-handed, native speakers of Spanish (i.e., contact since birth and dominant language at time of testing), from the College of Humanities at the UABC in Tijuana, Baja California, Mexico (mean age: 20.6 years; range: 18–27), were paid for their participation. None had auditory, cognitive or language disabilities.

Testing. Participants were randomly assigned to one of the five lists and were tested individually in a quiet room. Sentence stimuli were presented using PsyScope software, via headphones with adjustable volume connected to the sound amplifier port of a Macintosh PowerBook 3400cs. Voice responses were collected by a built-in microphone in the headset, separately connected to a CMU button box, designed to log millisecond-precision response times via the Macintosh modem port. During testing, the experimenter monitored the stimuli and responses through headphones and hand recorded naming errors. For verification purposes, an external tie-microphone recorded verbal responses to a magnetic tape recorder.

Participants received instructions in Spanish before a brief practice session, consisting of two sentences for each condition similar to those in the test session. They were told to fixate on crosses (“+ +”) that appeared in the centre of the computer monitor while listening carefully to a series of sentences. At some point, the auditory presentation paused and a picture replaced the crosses, remaining on the screen for three seconds or until they responded. Participants were asked to name the picture as soon as it appeared, using a single noun and nothing else (e.g., no articles). The picture disappeared as soon as the microphone perceived a sound onset, followed by a 500 ms delay, after which the auditory stimulus continued accompanied by a blank screen. A one-second ISI occurred after each sentence pair and before the next. Multiple-choice questions related to an

item just presented appeared on the screen randomly after 10% of the sentences to monitor participant attention. Participants responded by pressing a number on the computer keyboard with no time pressure. Experimental sentences were randomly presented in a continuous sequence. A failure to respond (NR) was automatically marked in the data file if the image disappeared prior to the participant's response. There was a break after half of the trials; participants continued when ready. The entire testing session lasted approximately 45 minutes.

Results

Errors. Voice key error (irrelevant noise or failure to perceive sound) and mechanical error led to 2.6% data loss. Additional items removed, but not considered naming errors, were synonyms (5.8% of data), for example, gender-matching synonyms when a non-matching condition was intended, like *el balón* versus *la pelota*—interchangeable synonyms for “ball” of opposite gender, and valid synonyms, like *el pelo* instead of the dominant response *el cabello*, both meaning “hair”. All other responses were coded for naming errors, with 5.9% true naming errors (93.5% naming accuracy), consisting of blatantly misnamed items (e.g., saying “lizard” for an image of a squirrel) and no responses. Analyses were done on the remaining responses (85.7% of all trials).

Response times. Mean response times were subjected to a within-subject analysis of variance with two levels of gender agreement (matching or mismatching) and two levels of semantic congruity (congruous or incongruous), over both participants (F_1) and items (F_2). There were main effects of gender agreement, where gender-mismatching pictures were named significantly slower than matches, $F_1(1, 35) = 45.03, p < .0001$; $F_2(1, 109) = 100.21, p < .0001$, and semantic congruity, where semantically incongruous pictures were named significantly slower than congruous items $F_1(1, 35) = 40.29, p < .0001$; $F_2(1, 109) = 51.23, p < .0001$. See Table 1 for mean response times and standard error values per condition. In addition, the effects of gender agreement and semantic congruity interacted, $F_1(1, 35) = 9.57, p < .005$; $F_2(1, 109) = 7.668, p < .006$.

Planned comparisons across all conditions over subjects and items, were significant at $p < .025$, with one exception: gender matching—semantically incongruous (G+S−) versus gender mismatching—semantically congruous (G−S+) conditions were marginally significant over subjects ($p < .06$) and not significantly different over items ($p < .59$). The fastest naming times were elicited when both gender and semantic cues were congruous and the slowest were elicited when both cues

TABLE 1

Picture naming times for Experiments 1a and 1b; Judgment times for Experiment 2. Mean response times and standard error in ms for experimental and neutral conditions, comparing naming times across Experiment 1a with the simple command neutral condition, Experiment 1b with the low-cloze neutral condition, and semantic judgment times in Experiment 2 (no neutral).

| Condition | Experiment 1a | | Experiment 1b | | Experiment 2 | |
|---|---------------|----|---------------|----|--------------|----|
| | Mean | SE | Mean | SE | Mean | SE |
| Gender Matching— Semantically Congruous | 757 | 27 | 715 | 15 | 943 | 46 |
| Gender Matching— Semantically Incongruous | 893 | 29 | 866 | 20 | 1023 | 53 |
| Gender Mismatching— Semantically Congruous | 932 | 34 | 896 | 26 | 1092 | 64 |
| Gender Mismatching— Semantically Incongruous | 980 | 39 | 951 | 25 | 1013 | 51 |
| Gender Neutral— Semantically Neutral | 877 | 31 | 878 | 19 | – | – |

mismatched. Gender or semantic violations alone elicited approximately equally slowed naming times, with marginally faster times for semantic than gender violations.

Each experimental condition was then compared with the cued naming responses for the same pictures in the simple neutral sentences, using simple one-way analyses of variance over participants and items, with a corrected $p < .025$ for significance (neutral sentences were not part of the factorial design, thus could not be considered for planned comparisons). Semantically congruous—gender matching pictures (G+S+) elicited significantly faster naming times, $F_1(1, 35) = 43.52, p < .0001$; $F_2(1, 109) = 47.62, p < .0001$, and semantically incongruous gender mismatching pictures (G-S-) elicited significant slower times, $F_1(1, 35) = 15.22, p < .0004$; $F_2(1, 109) = 34.89, p < .0001$, relative to neutral items. Gender mismatching—semantically congruous pictures were named marginally slower than the neutral condition, $F_1(1, 35) = 5.078, p < .03$; $F_2(1, 109) = 2.95, p < .09$; gender matching—semantically incongruous pictures did not differ from the neutral condition, $F_1(1, 35) = 0.94, p < .34$; $F_2(1, 109) = 2.22, p < .14$.

Discussion

The results from Experiment 1a indicate that gender agreement and semantic congruity both influence picture processing during on-line

comprehension when overt production of the lexical item is required. Gender agreement had a reliable effect on picture naming times, with significantly slower naming times for items that mismatched in gender with the preceding article than matches. Likewise, semantically congruous pictures were named faster than items that did not fit the preceding sentence context. In addition, the effects of gender agreement and semantic congruity interacted. Gender matching—semantically congruous pictures were named fastest, pictures were named at roughly the same rate when they were semantically incongruous (marginally faster) or gender mismatching, and gender mismatching—semantically incongruous items (double violations) were named slowest. However, the average naming time for the double violations was less than the sum of the two independent violations' naming times, hence the interaction. Relative to the neutral sentences there was significant facilitative priming for semantically congruous gender matching pictures and significant inhibitory priming for semantically incongruous gender mismatching pictures. When only one of these cues was inconsistent, either semantic incongruity or gender mismatch, participants responded at roughly the same rate as in the neutral condition, which provided no information about the target's identity. If anything, gender violations were named marginally slower than the neutral baseline and semantic violations. Hence, participants seemed equally disconcerted by either type of violation, behaving as if they were "starting from scratch" relative to a simple command to name an unpredictable upcoming picture.

The assumption here is that performance below (faster than) baseline indicates a facilitative effect of priming while performance above (slower than) baseline indicates inhibitory priming. Yet, this interpretation is, of course, dependent upon the validity of this particular neutral condition. The average picture naming time in the neutral condition in Experiment 1a was 877 ms (SE 31 ms). Average naming times out of context for the same set of experimental pictures was 946 ms based on data from a cued-naming task previously collected from 50 monolingual native speakers of Spanish by Bates et al. (2000). Hence, despite having no predictive value for any particular target on the basis of semantic or gender information, pictures are named significantly faster embedded in these simple command sentences than out of context. Nevertheless, these neutral sentences may provide a different processing load relative to the four experimental conditions. That is, participants listened to speech in the experimental sentences that built sentential context with prosodic cues and sentence intonation with at least some indication that a noun slot might be coming up. When the picture appears this flow of context is briefly interrupted, then continued when the picture disappears. In contrast, the simple command sentences provided little sentential processing load or context

and did not continue after the picture, causing less strain on short-term memory to maintain the sense of the sentence. These sentence-structure and processing-load differences between the experimental and simple-command sentences may have led us to underestimate the amount of facilitation and overestimated the amount of inhibition relative to this baseline (e.g., the marginal inhibitory effect for gender agreement violations).

To better understand the contribution of the baseline itself to our findings, Experiment 1b replicates Experiment 1a with a new set of neutral sentences—low-cloze gender-neutral sentence pairs to provide a neutral baseline comparison closer to the experimental sentences in structure and processing load.

EXPERIMENT 1B: PICTURE NAMING WITH LOW-CLOZE GENDER-NEUTRAL SENTENCE PAIRS AS A BASELINE

Method

Participants. A new group of 35 (8 males; 27 females) right-handed, native speakers of Spanish (i.e., contact since birth and dominant language at time of testing), students of the College of Humanities at the UABC in Tijuana, Baja California, Mexico (mean age: 23.6 years; range: 19–43), were paid for their participation. None had auditory, language, or cognitive disabilities.

Procedure. Experimental apparatus, mode of presentation, pre-testing and testing conditions, recording and error coding were identical to those in Experiment 1a. The stimulus sentences were identical to Experiment 1a, except that the simple command sentences were replaced with gender-neutral low-cloze sentence pairs with embedded line drawings. These neutral sentences were similar to the experimental sentences in length and sentential structure, but the sentence context allowed for any picture to be inserted sensibly with cloze probability essentially at zero. In addition, the picture target could appear in either sentence of the pair, but was never sentence final and was not preceded by an article. For example:

Gender and Semantically Neutral

*Armando tenía un examen en el que tenía que nombrar **ESCOBA** / **VELA** cinco veces. La maestra lo hacía para que tuviera buena pronunciación.*

Armando took an exam in which he had to name **BROOM** / **CANDLE** five times. The teacher would do this so that he would have good pronunciation.

The same 110 pictures appeared across the 5 sentence conditions and were distributed over 5 lists, such that each sentence pair and picture target appeared once per list. Participants were instructed to listen to the sentences and then name the picture target as soon as it appeared on the screen, as in Experiment 1a. Approximately 10% of the sentence pairs were followed at random by a multiple-choice question to ensure that the subjects were attending to the semantic content of the utterance. Response times in milliseconds and response accuracy were measured.

Results

Errors. Voice-key failure and mechanical error led to 1.8% data loss. In addition, 1.8% of the data were eliminated as synonyms of opposite gender (e.g., *balón—pelota*) and 2.4% of data as valid synonyms (e.g., *pelo—cabello*), but were not considered naming errors, and 4% of the data were true naming errors and no-responses (96% naming accuracy). Analyses are based on the remaining 90% of all trials.

Response times. Response times were subjected to a within-subject analysis of variance, with 2 levels of gender (matching and mismatching) and 2 levels of semantic congruity (congruous and incongruous), over both participants (F_1) and items (F_2). Note that one item (i.e., “*abrigo*”, coat) was eliminated because of an empty data cell in one condition after removing valid synonyms, hence the following analyses were done with 109 items rather than 110.

The results show a main effect of gender agreement, with significantly faster naming times for gender matching than mismatching pictures, $F_1(1, 34) = 64.93, p < .0001$; $F_2(1, 108) = 150.64, p < .0001$, and a main effect of semantic congruity, with significantly faster naming times for semantically congruous than incongruous items, $F_1(1, 34) = 42.46, p < .0001$; $F_2(1, 108) = 73.89, p < .0001$. Table 1 shows the mean naming times and standard error for each condition compared across Experiments 1a and 1b. There was also a significant interaction between gender agreement and semantic congruity, $F_1(1, 34) = 18.93, p < .0001$; $F_2(1, 108) = 12.20, p < .001$. Figure 1 illustrates this interaction; the dashed line indicates performance on the neutral condition.

Planned comparisons over subjects and items were significant at $p < .001$, with one exception: the comparison between the gender matching—semantically incongruous condition (G+S−) and the gender mismatching—semantically congruous condition (G−S+) was marginally significant over subjects ($p < .06$) and not significant over items ($p < .16$). As in Experiment 1a, naming times were fastest when both gender and semantic cues were congruous and slowest when both cues were inconsistent; either

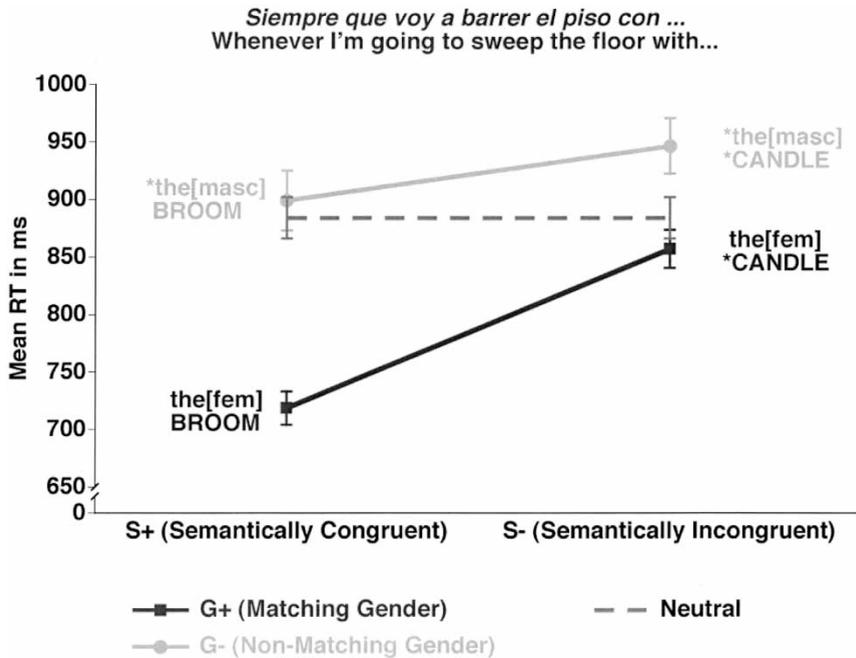


Figure 1. Interaction in picture-naming task between gender and semantic priming (ms), with standard error bars. This illustrates the gender agreement effect for semantically congruent and incongruent drawings; dashed line represents same drawings in the neutral baseline condition.

gender or semantic violations alone elicited approximately equally slowed naming times, with marginally faster times for semantic than gender violations (Table 1).

One-way analyses of variance over participants and items compared the neutral baseline to each condition, using a predetermined corrected $p < .025$ for significance (neutral sentences were not part of the factorial design). Another item (i.e., *estomago*—stomach) was excluded, because of an empty data cell in the neutral condition, leaving 109 items in three comparisons (minus *estomago*) and 108 in one comparison (minus *estomago* and *abrigo* from above). Gender matching-semantically congruous pictures were named significantly faster than the same pictures in a neutral sentence, $G + S +$: $F_1(1, 34) = 1.13E2$, $p < .0001$; $F_2(1, 108) = 1.04E2$, $p < .0001$, whereas gender mismatching-semantically incongruous pictures were named significantly slower, $G - S -$: $F_1(1, 34) = 20.22$, $p < .0001$; $F_2(1, 107) = 19.58$, $p < .0001$. When pictures were either gender mismatching or semantically incongruous alone, they did not differ significantly from the neutral condition [$G + S -$: $F_1(1, 34) = 0.45$, $p <$

.51; $F_2(1, 108) = 1.38, p < .24$; G-S + : $F_1(1, 34) = 0.98, p < .33$; $F_2(1, 108) = 0.01, p < .92$.

Discussion

Mean response times for participants in Experiment 1b were slightly faster as a group than in Experiment 1a. Nevertheless, Experiment 1b replicated the main effects of gender agreement and semantic congruity from Experiment 1a, as well as the interaction between them. In addition, the relationship between the experimental conditions and neutral condition was practically identical to that between the experimental conditions and original baseline, with the exception that the marginal inhibitory effect of gender violations was now not significant. Hence, the current neutral sentences appear to provide similar priming, if not slightly closer to the experimental conditions, as simple commands to name a picture, which may provide no more than an opportunity to prepare for a verbal response. We can conclude that the facilitative and inhibitory effects observed in Experiment 1a were not likely due to differences in sentential structure between the experimental and neutral sentences. It is important to note that these same pictures were named significantly slower out of context (~946 ms) in the Bates et al. study (2000), where pictures appeared after a visual fixation and a tone, compared with either of our neutral conditions. Despite the absence of specific semantic or gender information, our neutral sentences have additional prosodic cues, time to prepare a response, and/or some sort of general metalinguistic priming that brief tones do not. That is, they provide a linguistically rich setting, more closely related to the experimental sentences. Therefore, comparing the effects of semantic congruity and gender agreement relative to these neutral sentences in Experiments 1a and 1b shows facilitative and inhibitory priming beyond what can be elicited by rich prosodic, but gender-unmarked weak semantic sentences.

Adding semantic predictability from sentential context and the gender-agreement relationship between the article and noun in the experimental sentences elicited significant facilitative priming when both cues were consistent and significant inhibition when both cues were inconsistent, relative to either neutral condition. Interestingly, picture-naming times were identical to naming these pictures in neutral sentences when only one of these cues was inconsistent, as if, any one violation “neutralised” the facilitative or inhibitory priming effect. The fact that the double violations elicited an additional slowing, and thus inhibition relative to the neutral sentences, indicates that when combined they can lead to increasingly more difficulty in processing a target.

Note however that these contributions are not simply adding to elicit “doubly” slowed response times, hence the interaction between gender agreement and semantic congruity. For example in Experiment 1b, if the contributions were linear, the independent response delays from gender mismatches and semantic anomalies, 181 and 151 ms respectively on average, would elicit an additive delay of 332 ms for the double violations. However, the double violations were only 236 ms slower on average than the congruous-gender matching sentences; a highly significant 96 ms difference. It could be argued that this interaction simply reflects a ceiling effect, such that it might be physically improbable for participants to name the pictures any slower. We think this is unlikely, particularly since the participants in Experiment 1a had slower naming times overall, yet showed the same pattern of effects from Experiment 1b. If naming times for the double violations were at ceiling for Experiment 1b, then the conditions in Experiment 1a would simply have moved closer to that ceiling, potentially eliminating the difference between the double and single violation (and neutral) conditions. They did not. Moreover, other studies have shown similar interactions with slower/faster overall response times (e.g., Bentrovato et al., 1999; Roeder, Demuth, Streb, & Roesler, 2003). For example, Roeder et al. (2003) found a similar interaction between gender agreement (between an adjective and noun presented in isolation) and semantic priming in German auditory word perception, using a lexical decision task with both sighted and blind individuals. Blind individuals showed overall faster response times than sighted participants, but the pattern of effects remained the same across groups. Using similar stimuli and experimental design to ours, Bentrovato et al. (1999) showed that in Italian this interaction between gender and semantic priming remained consistent even after repeated exposure to the same stimuli, when overall response times were significantly faster. Again, given that the overall response times shifted, but the pattern of interaction did not, the double violations cannot be at an absolute ceiling.

It is unclear, however, how much of this pattern of effects is due to actually naming the pictures (i.e., pronouncing the name out loud), as opposed to gender agreement having an effect on picture processing or integration. Therefore, in Experiment 2 we replaced naming with a semantic judgment task to determine if gender agreement influences response times in a comprehension task where naming is not required, and whether or not it affects semantically congruous and incongruous pictures equally.

EXPERIMENT 2: GENDER PRIMING FOR SEMANTIC JUDGMENT OF A PICTURE IN A SPANISH SENTENCE

Pictures have often been used, both in isolation and in a sentence context, to address questions about lexical access (e.g., Bentrovato et al., 1999; Glaser, 1992; Jacobsen, 1999; Jescheniak, 1999; Levelt, Schriefers, Vorberg, & Meyer, 1991; Levelt et al., 1999; Potter, 1986; Potter & Faulconer, 1975; Schmitt, Meyer, & Levelt, 1999; Schmitt, Rodriguez-Fornells et al., 2001a). However, the extent to which pictures and words share a common representation in the brain is a matter of long-standing debate (see Federmeier & Kutas, 2001 for a comprehensive discussion of electrophysiological and behavioural evidence). Differences in response times between word reading versus picture naming, and differences in cross-modal versus single-modality priming effects have led some to propose that there are separate underlying processing systems for words and pictures, wherein both conceptual and lexical representations for a concept are stored (e.g., dual-coding models Paivio, 1991; Shallice, 1988). At the same time, evidence that words and pictures are processed equally fast or effectively when the task requires semantic processing, but not when the task requires lexical level processing has led some researchers to conclude that pictures and words share a semantic representation, but that lexical level information, such as gender, is directly accessible only by words and not pictures (e.g., single code models; Potter, 1986). For example, Bowers et al. (1999) showed that semantic decisions (i.e., man-made or natural kind) were made faster for pictures than words, but gender decisions in Spanish (i.e., masculine or feminine) were made faster for words than pictures. The authors inferred from these data that grammatical gender is more closely linked to lexical than conceptual representations. Pictures presented *in isolation* provide an ideal stimulus for observing the processes of word production from accessing a concept to vocalising its lexical equivalent (e.g., Levelt, 1989). Pictures have also been used, however, to test the effects of syntactic and semantic priming on picture naming *within a sentence context* (e.g., Bentrovato et al., 1999; Hillert & Bates, 1996; Jacobsen, 1999), hence embedding a measure of word production within a sentence comprehension task. Some studies have shown strong influences of syntactic priming on naming a picture, with average naming times similar to those observed in semantic priming tasks (e.g., Potter, 1986). Nonetheless, studies rarely have shown a syntactic-priming effect using a measure that did not require overt or tacit naming to determine whether this information becomes available during *comprehension* of a picture.

Experiment 2 uses a semantic judgment task in order to address whether or not pictures are susceptible to syntactic priming from a gender-marked article even when overt naming is not required. To elicit an effect of gender priming, being mindful that grammatical gender is a property of the word, not the object (e.g., a broom is neither feminine nor masculine, *per se*), the syntactic features of words represented by the pictures must be accessed at some point during the process of integrating the picture. This might imply that the picture's lexical equivalent is either pre-activated based on sentence context, or activated automatically on picture presentation. Note, however, that the latter explanation would contradict findings (mentioned above) that pictures are processed more slowly and elicit less priming on lexical tasks than words, because pictures are assumed to have no direct access to their lexical equivalent. It has already been established that cross-modal priming occurs between words and pictures (see also Federmeier & Kutas, 2001; Ganis, Kutas, & Sereno, 1996; McPherson & Holcomb, 1999; Nigam, Hoffman, & Simons, 1992; Potter, 1986; Potter & Faulconer, 1975). If pictures share a common semantic representation with words, but gender is accessed only with overt word production, then listeners should be able to bypass discordant syntactic level information during a pure comprehension task and integrate the picture into the sentence context by accessing its semantic or conceptual level representation directly. If however, pictures show an effect of gender priming, then this information must be available at some stage of comprehending or integrating the picture into the sentence, even when explicit access to the name is not required.

Method

Participants. A new group of 24 (9 males; 15 females) right-handed, native speakers of Spanish, students at the college of Humanities of the UABC in Tijuana, Baja California, Mexico (mean age 21.4 years; range 20–25) were paid for their participation. None had auditory, cognitive, or language disabilities.

Materials. The stimuli consisted of the same 110 experimental sentence pairs and pictures from Experiment 1a. The neutral sentences were inappropriate for the task—yes/no judgement regarding the semantic fit of a picture to the sentence—hence, were eliminated. This resulted in a total of 440 stimulus sentence pairs distributed across four lists, such that each sentence pair and each picture appeared once per list.

Procedure. The stimuli were presented exactly as in Experiment 1a. The practice set was identical to Experiment 1a, minus the two neutral

sentences. Participants were instructed in Spanish as in Experiment 1a, but were now asked to determine whether or not the picture was a good continuation of the sentence semantically by pressing the corresponding button on the CMU device. The buttons were clearly marked by response type (i.e., smiling or frowning face above the appropriate button) and were counterbalanced across participants, such that half pressed the left and right button for good and bad continuations respectively, and half did the opposite. Participants were asked to keep one finger on each button, to avoid saccades away from the monitor.

The same experimental set-up was used as in Experiment 1a, with the exception that all voice-recording devices were eliminated. Instead, the CMU device, connected to the PowerBook modem port, was used to record button-press responses in milliseconds. Participants were asked to respond as quickly as possible after the image appeared on the screen. The image disappeared after 3 s or when the participant responded, and the auditory presentation of the sentence continued. There was a 1 s delay between sentence pairs. Multiple-choice questions appeared randomly after 10% of sentences to monitor participant attention. There was a break after half of the sentence pairs; the experiment continued when the participant was ready. The entire experimental session lasted approximately 45 minutes.

Results

Errors. Participants were 96.4% accurate (only 3.6% judgement errors) at correctly judging the semantic fit of the target. No further analyses were performed on the error data and all remaining analyses are based on the accurate responses.

Response times. The term GOOD will refer to instances when the participant correctly determined that a target made sense within the sentence, and BAD when the participant correctly determined that it did not make sense. Mean response times were subjected to a within-subject analysis of variance with two levels of gender agreement (matching or mismatching) and two levels of semantic fit (GOOD or BAD), over participants (F_1) and items (F_2). The analysis yielded a significant main effect of gender, where gender-matching pictures were judged significantly faster than mismatches, $F_1(1, 23) = 15.83, p < .001$; $F_2(1, 109) = 28.72, p < .0001$, but no effect of judgment type (fit), $F_1(1, 23) = 0.001, p < .97$; $F_2(1, 109) = 0.58, p < .45$. There was, however, a significant interaction between gender agreement and judgment type, $F_1(1, 23) = 30.31, p < .0001$; $F_2(1, 109) = 43.06, p < .0001$, illustrated in Figure 2.

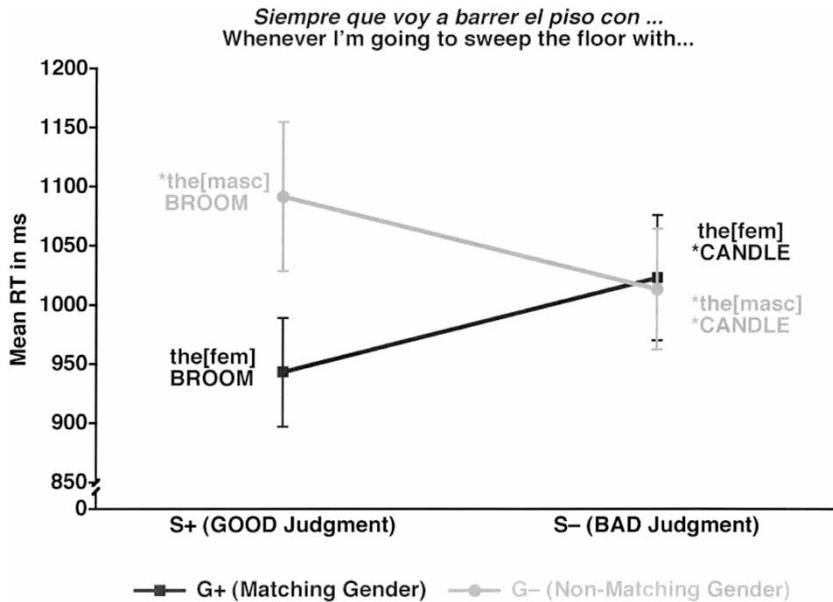


Figure 2. Interaction in semantic judgment task between gender and semantic fit (judgment type) (ms), with standard error bars; where GOOD instances required the participant to respond that the picture target was a sensible continuation of the sentence semantically, and BAD instances required the participant to respond that the picture target was a semantically incongruent continuation of the sentence.

Planned comparisons over participants and items were reliable at $p < .004$ for all pair-wise comparisons, except one: semantically incongruous gender matching and mismatching pictures did not differ over subjects ($p < .77$) or items ($p < .89$). Response times were fastest for gender matching—semantically congruous items and slowest for gender mismatching—semantically congruous items.

Discussion

As with picture naming, gender agreement between an article and picture's name had a significant effect on response times for judging a picture's semantic fit within the sentence. However, the nature of this effect differed between the two tasks. In the semantic-judgment task, the effect of gender agreement was observed only on semantically congruous items (requiring a GOOD judgment), producing the fastest responses with a gender match and the slowest with a gender mismatch; in Experiment 1(a & b), gender-agreement violations elicited only marginally slower naming times than semantic violations. In contrast, gender agreement had no effect on

semantically incongruous items (requiring a BAD judgement); in Experiment 1(a & b) the slowest naming times were observed for double violations.

The results from Experiment 2 indicate that grammatical gender can influence the integration of a picture into a sentence, even in the absence of the overt (spoken) word and in a comprehension task that does not require explicit naming. Given that grammatical gender is a property of a word and not the concept, *per se*, this implies that gender information of the picture's word-equivalent must have been accessed in order to (mis)match agreement with the preceding article (see also Wicha et al., 2003a, 2003b, 2004). However, overt naming, that is, accessing the phonological level information of the word, is not required for gender to affect semantic level integration, confirming that the results from Experiment 1 (a & b) were not purely due to the production part of the task. Given these data, one might even argue that gender information is stored or linked to the lexical-semantic level of a concept, and that direct access to the word form is not necessary.

Note, however, that mean naming times in Experiment 1 (a & b) were much faster than judgment times in Experiment 2. During this delay, participants might have been able to name the picture silently before giving their response. In this case, one might argue that naming is required for gender agreement to affect semantic integration. A task that requires only shallow processing of the pictures, such as a judgment on the picture itself (e.g., big/small; animate/inanimate), might be a more accurate measure of how well gender can penetrate semantic priming than the task we used herein. However, even these tasks could not guarantee that a listener is not naming prior to making a judgment. In addition, if participants were naming in the current experiment, semantically congruous nouns might have always had a priming advantage, leading to faster judgment times over incongruous ones. This was not the case. Judging an item as semantically congruous when preceded by a gender-mismatching article elicited the slowest response times overall. Moreover, if participants were naming in both tasks picture naming versus semantic judgment—it would be difficult to explain the difference in the pattern of results across the tasks for the double violations. Experiments 1a and 1b revealed a sub-additive naming delay for gender violations on semantically incongruous items that was not observed in Experiment 2. This difference must be explained by something beyond whether listeners are tacitly naming, and may in fact reflect two distinct roles for gender agreement in production versus comprehension. Specifically, it appears as though the gender cue on the article has both a global effect on the larger sentence context and a local effect between adjacent gender-marked words during sentence processing (e.g., Robertson & Lamb, 1991).

The global effect may stem from an active process in which listeners combine semantic and gender information to build an expectation based on context for an upcoming concept and its associated noun. Response times for judgments are generally slower than naming (e.g., Potter & Faulconer, 1975), with the assumption that this response delay is due to making a mental judgment in addition to a motor response, as opposed to a more automatic process of producing a word. Participants were extremely accurate at judging the semantic fit of pictures in Experiment 2. However, average judgment times were significantly slower than average naming times for the same items in Experiment 1a and 1b, consistent with previous findings. We cannot be sure that our participants were not tacitly naming the pictures (consciously or not) during this delay before making the judgment, but the difference in overall pattern of effects across Experiments 1 and 2 indicates otherwise. Furthermore, this type of strategic priming effect (e.g., Neely, 1991) is unlikely given the stringent controls of the stimuli (see also Griffin & Bock, 1998). Only 0.40 of the items (22 of 110 per list) were semantically consistent with the preceding contexts which varied in cloze (range 0.41–1) and 0.20 of which were preceded by an inconsistent article; 0.60 of the pictures were completely unpredictable (neutrals or semantically incongruous). Moreover, the picture's location in the sentence was unpredictable since it could appear in either the first or second sentence of each pair, was never sentence final and was preceded by an average of 2 article-noun pairs. Rather, the gender mismatch effect in Experiment 2 is compatible with the idea that the article preceding the target adds to the sentence context, making it more difficult to integrate the upcoming noun (picture) when it mismatches in gender and easier when it matches.

This global effect of gender could either work during integration of the picture, and/or prior to the picture's presentation. In the latter case, the sentence context prior to the article may allow the listener to expect (consciously or not) the next word based on context (particularly for high cloze items). Hence, the listener might expect the sentence to continue, for example, with "the broom", which in Spanish would of course include a gender-marked article, *la escoba*. If this expectation is fulfilled at the article, the listener should continue to expect *escoba*. However, the article *el* would violate their expectation for "broom" before the picture appeared, even though the sentence could continue with an item of masculine gender that agrees with the context and preceding article (e.g., *el trapo*—the rag). Thus perhaps, in Experiment 2 when a congruous picture—hence initially expected based on sentence context (e.g., *escoba*—broom)—mismatches in gender with the preceding article (e.g., *el*), there is an additional delay in order to reassess whether that item is actually consistent with the sentence after all. On the other hand,

semantically incongruous pictures—hence unpredictable based on sentence context (e.g., *vela*—candle), are perhaps judged as such, disregarding the gender of the item at that point. Recent event-related potential studies, analysing the brain’s response to an “unexpected” article of this sort, may provide support for this idea. Using the sentences from the current study, Wicha and colleagues (Wicha et al., 2003a, 2003b, 2004) observed a consistent brain response to spoken articles that were grammatical and plausible continuations of the sentences, but unexpected based on prior context. In other words, it seems that the gender of the article contributes to the meaning of the sentence as it unfolds, enabling expectations (or predictive processes), leading to faster picture integration when that expectation is met and slower integration when it is not.

Additional support for semantically and morphosyntactically driven predictive processes, similar to the ones we propose herein, comes from recent studies by Kamide, Altmann, and colleagues, in English (Altmann & Kamide, 1999; Kamide, Scheepers, & Altmann, 2003b), Japanese (Kamide, Altmann, & Haywood, 2003a; Kamide & Mitchell, 1999) and German (Kamide et al., 2003b). In these studies the authors used simultaneous presentation of a spoken sentence and a real-world scene, and monitored eye movements as the sentence unfolded. In all languages, (morpho)syntactic level information and semantic information lead to *anticipatory* saccades to an object in the scene before the name of that object was pronounced. For example, in German (Kamide et al., 2003b) case information on nouns provides critical information about the arguments in a sentence, such that in sentences with the same word order, like *Der Hase frißt gleich den Kohl.*—“The hare[nom] eats shortly the cabbage[acc].”, the nominative [nom] case indicates that the hare is likely the agent of the sentence, versus *Den Hasen frißt gleich der Fuchs.*—“The hare[acc] eats shortly the fox[nom].”, the accusative [acc] case indicates that the hare is likely the object. Using sentences like these, Kamide et al. observed increased saccades toward the appropriate object in the scene corresponding to the manipulation of the case-marking information at the first noun (e.g., hare[nom] elicited eye movements to cabbage and hare[acc] to fox), even before the object was pronounced in the sentence. However, anticipatory eye movements did not occur until after the verb, indicating that listeners integrated the syntactic information from the case markings and the semantic information from the verb prior to making anticipatory saccades. Hence, morphosyntactic information, such as case in German and Japanese, verb morphology in English and presumably grammatical gender in Spanish, can contribute to the sentential context during on-line comprehension to anticipate and integrate upcoming words.

The local effect of gender, in contrast, is likely caused by the morphosyntactic mismatch between the article and noun (picture),

inhibiting the overt production of that noun (see Marslen-Wilson & Tyler, 1980, 1981, for a related discussion of local vs. global effects in auditory word comprehension). To understand how this local effect might work, we must be mindful that nouns in Spanish are rarely pronounced in isolation. Even when naming an object out of context in conversation, it is uncommon to say the noun *escoba* instead of *la escoba* or *una escoba*. Furthermore, adjectives are far more likely to occur after the noun, leaving the article and noun together as a contiguous unit (e.g., *la escoba vieja* “the broom old”). Therefore, since the article and noun are so often pronounced as a pair, they may be considered a unit at the level of phonology or motor planning, with components that are difficult to separate. Dahan et al. (2000) provide a similar argument for the co-occurrence of article-noun pairs in French. The authors used an eye monitoring task with a factorial-design array of pictures, whose names in French could either share an initial phoneme (called “cohorts”) or not, and share gender or not, and asked participants to click on the appropriate picture corresponding to a spoken noun. Participants fixated cohort words equally in the absence of gender information, but when a gender-marked article preceded the noun, participants fixated the gender-sharing pictures instead. The authors concluded that the gender of the article interacts early with other lexical features to constrain the potential candidates for word recognition, and that this effect could be in part due to the high frequency of co-occurrence for article-noun pairs in French (e.g., a local effect of gender agreement). Similarly, in a small but informative set of errors in Experiment 1, participants sometimes completed the incorrect masculine article *un* with the fragments [-na] or [-a], perhaps to make the article consistent with the feminine name they were about to pronounce. Therefore, when forced to pronounce a noun that is inconsistent with the gender of the preceding article in the double violation condition in Experiment 1, we observe a response-time delay in addition to the “global” effect of gender agreement—the only effect observed without overt production in Experiment 2 (see also Griffin and Bock, 1998 for a thorough discussion of phonological level influences on word production processes).

In sum, the results from Experiment 2 indicate that gender agreement affects the integration of a picture into a sentence context even when the task does not require explicit naming. The difference in the interaction between gender agreement and semantic congruity when naming or judging the semantic fit of a picture may reflect two distinct roles that gender can play in sentence processing: a global effect on the construction of a sentence’s meaning during comprehension and a local effect of a gender-marked article on the production of a noun.

GENERAL DISCUSSION

Our findings demonstrate that grammatical gender agreement can influence the integration of a picture into a sentence and the ability to name that picture when performing a sentence comprehension task. In addition, gender agreement interacted with semantic congruity in both tasks, albeit differently. In brief, semantic congruity had a significant effect on the time it took to name a picture, with faster times for congruous than incongruous pictures, confirming previous findings that pictures are sensitive to cross-modal semantic priming from a sentence context. Gender agreement between an article and noun (picture name) also had an impact on picture naming times, where pictures were named faster preceded by a gender-matching article than mismatches. In addition, gender agreement and semantic congruity interacted to elicit the fastest naming times, as well as facilitative priming relative to two neutral baselines, for semantically congruous—gender matching pictures and slowest naming times, as well as inhibitory priming, for gender mismatching—semantically incongruous pictures. However, responses to these double violations were not as slow as if adding the individual contributions from gender agreement and semantic congruity violations alone. Gender agreement also had an effect on the time it took to judge a picture's semantic fit to the preceding sentential context, but only when the picture was semantically congruous. This difference between tasks may illustrate two distinct roles that gender plays during comprehension versus production.

Similar to the current study, Griffin and Bock (1998) used “rebus” sentences to test the interaction between lexical and conceptual level processes in naming sentence-final pictures in English. Their goal was to distinguish between two families of theories, the discrete-stage models (e.g., Butterworth, 1989; Garrett, 1980; Levelt et al., 1991; Levelt, 1989; Levelt et al., 1999; Roelofs, 1992) and “cascade” (including interactive-activation) models of speech production (e.g., Dell, Burger, & Svec, 1997; Dell, Schwartz, Martin, Saffran, & Gagnon, 1997). In general, word production models assume that there are two stages of word retrieval, lexical-semantic and syntactic retrieval (also called lemma access) and word-form retrieval (phonological information). In discrete models, word selection is generally assumed to precede phonological encoding, implying that activity during lemma selection does not affect phonological form selection, and vice-versa, leading to additive influences on production across the two stages. In contrast, cascade and interactive-activation models allow word forms to receive information about word selection (e.g., feedback), such that phonological encoding can begin before lexical selection is completed. In their study, Griffin and Bock (1998) manipulated

contextual constraints of the sentence, postulated to influence word selection processes, and frequency of the picture names, assumed to influence phonological form (though some argue that frequency affects contextual level information as well, e.g., Van Petten & Kutas, 1991a, 1991b), and found an interaction in that the advantage in naming high frequency words diminished as the contextual constraint increased. The authors interpreted these results to indicate that contextual constraint influenced phonological form activation by reducing the effect of frequency on word production in a non-linear fashion, supporting cascade models of speech production.

Similarly, our study may tap into these two levels of processing, as indicated by the difference across Experiments 1 and 2, with gender agreement affecting both contextual constraint (e.g., global effect) and lexical form information (e.g., local effect). One could argue that this difference can be explained as a difference in processing demands/costs between a more automatic task, producing a name for a picture, versus a less automatic judgment, requiring perhaps more metalinguistic processing than the latter and allowing for potential strategic processes. However, listeners could just as easily have developed strategies for naming the pictures as judging them, since predicting the response correctly, that is preparing the correct name or response ahead of time, is at chance or below in both Experiments 1 and 2. Moreover, assessing the fit of a concept within the meaning of a sentence is a natural and quite automatic process in normal language. In fact, the brain assesses semantic fit of a word or picture into a sentence context within 400 ms from the presentation of the stimulus (e.g., Kutas & Hillyard, 1980a, 1980b). Hence, listeners should be no more strategic when making a semantic judgment than naming pictures within a sentence context.

Some theories postulate that grammatical gender is part of a word's syntactic information at the level of the lemma, and gender is sometimes only activated with the intent of production (e.g., see discussion of gender module, Levelt et al., 1999). In addition, it is often assumed that the lemma level information is shared between processes of comprehension and production. In accordance, gender agreement affected picture integration in both Experiment 1, requiring noun production, and Experiment 2, requiring only semantic integration, indicating that in both comprehension and production, grammatical gender information is accessed and used during processing and integration of a depicted object. Moreover, it may be the case that gender interacts with word form level information. As mentioned earlier, Spanish (unlike gender-marked languages like German) has what is called transparent gender, that is, the gender of words (i.e., masculine or feminine) is highly correlated with the words' noun class (i.e., phonological form). For example, in Spanish, 99.9% of nouns ending

in “-o” are masculine, while 96.3% of nouns ending in “-a” are feminine (Teschner & Russell, 1984). An article’s gender is determined by the gender of the subsequent noun (and exceptionally by the word form, e.g., *el aguila*—the[masc] eagle[fem]). Therefore, the additional delay for the double violations in Experiment 1 might be attributed to grammatical gender (e.g., morphosyntactic information at the level of the lemma) having an effect on lexical form selection and production through its strong correlation with noun class phonology (e.g., local effect).

The peculiar title of this paper, “When zebras become painted donkeys”, refers to one of the errors that occurred in our word production data, reflecting what might be interpreted as a search for compromise among cues. For example, when given the sentence “I burned the oil in the[masc] . . .” and an image of a zebra appeared, several participants said “burro” or donkey. Zebra in Spanish is a feminine word, but donkey is masculine. Neither option (zebra or donkey) constitutes a good semantic completion (i.e., zebras and donkeys are both poor receptacles for burning oil), but *burro* at least matches with one cue in the sentence, the masculine article. Moreover, a donkey and a zebra are visually similar, particularly for residents of Tijuana, where a stroll down Revolution Avenue will provide any passerby with a plethora of donkeys painted to look like zebras! It seems that our Spanish speakers were trying to find solutions to the problems that we posed, solutions that take all the sources of information into account, satisfying as many as possible.

What kind of process might lie behind this pattern of results? The studies presented herein were motivated by an interactive-activation approach to the converging effects of grammatical gender and sentential context on lexical access in Spanish, in particular, a synthesis of the Competition Model (Bates & MacWhinney, 1989) and recurrent neural network models of linguistic perception and production (Elman, 1990a, 1990b, 1993). This model permits continuous, bi-directional feedback between meaning and form in both comprehension and production. Any source of linguistic information (semantic, morphological, phonological) can be used as soon as it is available; inputs to the lexical processor are computed by weighing information (activation) from different sources continuously, in parallel. Representations within this kind of network can be thought of, in an abstract sense, as a multidimensional space in which all linguistic information resides. Figure 3 illustrates a possible three-dimensional subset of this high-dimensional space, with special reference to Spanish gender. Along each axis of this space are the values of particular linguistic dimensions (e.g., number, gender, and the contrast between modifiers and nouns) that are contextually dependent and highly interactive with neighbouring phenomena. As information enters the system during on-line sentence processing, the network uses both syntactic

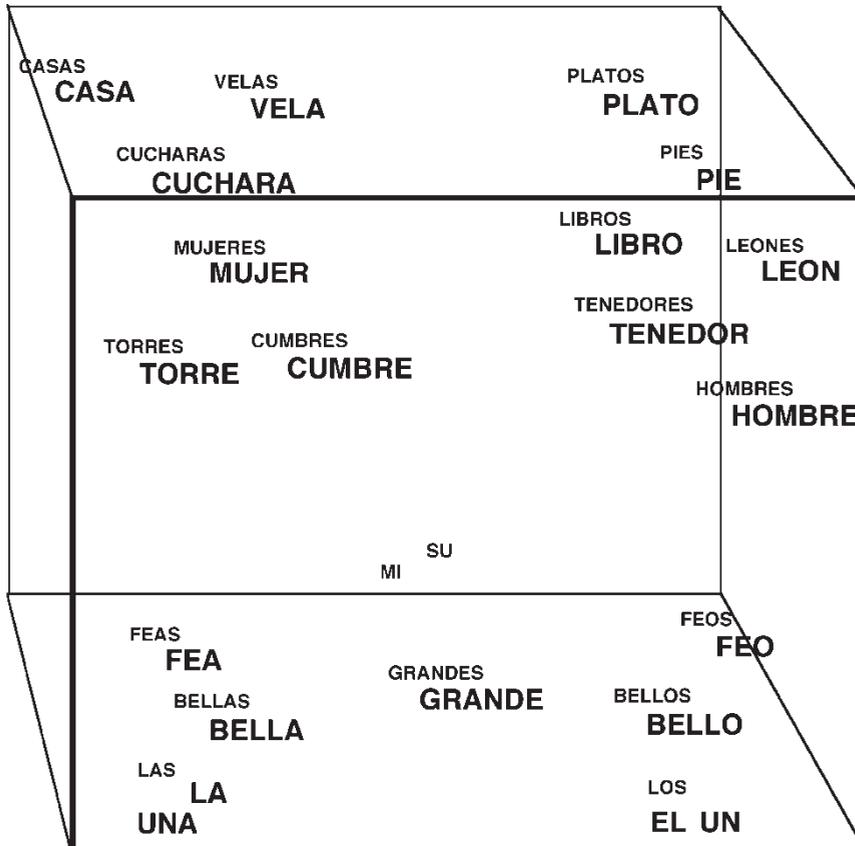


Figure 3. A three-dimensional space illustrating a hypothetical relationship among three linguistic dimensions (masculine vs. feminine gender from left to right; the noun-modifier contrast along the vertical dimension; a singular-plural contrast from back to front). Adapted with permission from Elman, 1990.

and semantic context to predict upcoming words. Predictions are defined as movements through this high-dimensional space toward the neighbourhood in which contextually appropriate items reside (e.g., from a gender- and number-marked modifier to a noun that agrees in number and gender, *inter alia*). Within such a system, even a small morphosyntactic cue, like gender agreement on a determiner-noun pair, could potentially influence expectations at a contextual level, moving the speaker/listener closer to where s/he will ultimately need to be when the target noun arrives.

The current study indicates that gender can contribute to sentence processing in different ways when pronouncing the name of an object, versus comprehending the concept. Naming during comprehension is a

fairly natural task, similar to when a listener interjects a word into a speaker's sentence once the concept has been activated by sentential context. In gender-marked languages, like Spanish, however, the gender of an article and noun appears to affect this process of naming during real-time comprehension. In addition, gender agreement between an article and noun appears to influence the integration of a sensible concept (picture) into a sentence context, even when overt production of the noun is not required. In sum, our results indicate that grammatical gender can play at least two roles in sentence processing, in comprehending a concept by contributing to the meaning of a sentence as it unfolds and by influencing the ability to produce a gender-marked noun (e.g., the global and local effects of gender agreement in comprehension and production, respectively). The listener attends to gender agreement cues during online spoken sentence comprehension, even in a task that does not require naming and/or the target noun is depicted, and uses these cues in combination with semantic level information from sentence context to rapidly make sense of the speaker.

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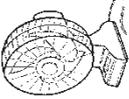
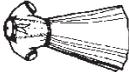
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Appendix I. Stimuli for Picture Naming and Semantic Judgment Tasks. Each sentence appeared once in one of its forms per subject along with one of the two pictures corresponding to it.
 Legend: ✓ = correct answer; * = incorrect pronoun; (del, al are contracted articles).

| sentences | mc question (randomly presented after sentence) | semantically congruent | semantically incongruent |
|--|--|--|--|
| 1) Como a mi abuela no le gusta volar, se nos hizo imposible convencerla de tomar un/*una _____ para venimos a visitar. A fin de cuentas nos pusimos de acuerdo que iba a tomar el tren. | 1) ¿Por qué viajó mi abuela por tren? ✓ 1) Porque no le gusta volar 2) Para visitarnos 3) Porque le gusta el paisaje 4) 1 y 2 |  |  |
| 3) El estudiante le regaló a la maestra una/*un _____ roja. El siempre trataba de ser el preferido de la maestra | 3) ¿Por qué le dio un regalo a la maestra? ✓ 1) Porque el estudiante era muy simpático 2) Porque el estudiante no la quería 3) Para tratar de ser el preferido 4) Para que se pusiera feliz |  |  |
| 6) A mi tío Roberto le gusta cazar sin rifle o escopeta. Recientemente se ha comprado un arco y una/*un _____ para completar su equipo. | 6) ¿Cómo le gusta cazar al tío Roberto? ✓ 1) Sin rifle o escopeta 2) Con sus amigos 3) Con rifles modernos 4) Con una pistola |  |  |
| 7) El doctor le aconsejaba a mi abuelo que no siguiera fumando. Como es terno siempre que venía a visitarnos llegaba con un cigarrillo en la mano pidiendo un cerillo y un/*una _____ a mi papá. | 7) ¿Qué hacía el abuelo para dañar su salud? ✓ 1) Seguía fumando 2) Hacía ejercicio demasiado pesado 3) Comía demasiado salado 4) 1 y 2 |  |  |
| 8) Cada vez que Jorge va al bosque corta la madera con una/*un _____ que le regaló su compadre. Después lleva la madera a la cabaña para que se mantenga la chimenea prendida. | 8) ¿Qué hace Jorge con la madera? ✓ 1) La vende 2) Corta la madera para hacer muebles 3) La mete en la chimenea 4) 1 y 2 |  |  |

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