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The thematic hierarchy in sentence comprehension: A study on the interaction between verb class and word order in Spanish

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Linking is the theory that captures the mapping of the semantic roles of lexical arguments to the syntactic functions of the phrases that realize them. At the sentence level, linking allows us to understand "who did what to whom" in an event. In Spanish, linking has been shown to interact with word order, verb class, and case marking. The current study aims to provide the first piece of experimental evidence about the interplay between word order and verb type in Spanish. We achieve this by adopting role and reference grammar and the extended argument dependency model. Two different types of clauses were examined in a self-paced reading task: clauses with object–experiencer psychological verbs and activity verbs. These types of verbs differ in the way that their syntactic and semantic structures are linked, and thus they provide interesting evidence on how information that belongs to the syntax–semantics interface might influence the predictive and integrative processes of sentence comprehension with alternative word orders. Results indicate that in Spanish, comprehension and processing speed is enhanced when the order of the constituents in the sentence mirrors their ranking on a semantic hierarchy that encodes a verb's lexical semantics. Moreover, results show that during online comprehension, predictive mechanisms based on argument hierarchization are used rapidly to inform the processing system. Our findings corroborate already existing cross-linguistic evidence on the issue and are briefly discussed in the light of other sentence-processing models.

Keywords: Thematic hierarchy; Psychological verbs; Word order; Sentence processing; Self-paced reading.

One fundamental aspect of studying language comprehension is understanding how different types of linguistic information are integrated online. In the past years, special attention has been paid to the integration between syntactic (form) and semantic (meaning) information, since this allows comprehenders to determine "who did what to whom" (Bader & Bayer, 2006; Bornkessel, Zysset,

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Friederici, von Cramon, & Schlesewsky, 2005; Brennan & Pylkkänen, 2010; Cupples, 2002; Paczynski & Kuperberg, 2011; Piñango, 2000, 2006, among others). At the sentence level, one way of studying syntax-to-semantics linking (or mapping) is by focusing on the establishment of argument hierarchies. These hierarchies determine an activity ranking of semantic roles (i.e., agents, effectors, experiencers, themes, patients, etc.). These roles are the semantic functions assigned to participants in the event described by a sentence. As an example, consider the sentence "John talked to Mary". Understanding this sentence involves (a) recovering the information that describes a situation where someone talked to someone else, (b) retrieving the participants involved in the event and identifying their semantic function, and (c) establishing the relation between these two participants by building a hierarchical representation in which the most active participant is interpreted as actor, which outranks the less active participant, the undergoer (cf. Van Valin & LaPolla, 1997). In other words, this third step requires that the parser determines who is the speaker and who is the addressee of the talking event. The primary goal of the present study is to shed light on the online implementation of the form-to-meaning linking mechanisms by examining hierarchical argument processing in Spanish, a language in which argument hierarchization result from the interaction of different factors: Word order (WO), verb class, and case marking are three of the most relevant. For instance, consider the sentences in Example 1:

1a. El chico le grita a la chica.
The boy$_{\mathrm{NOM}}$ clit$_{\mathrm{DAT}}$ yells to the girl$_{\mathrm{DAT}}$
1b. A la chica le grita el chico.
To the girl$_{\mathrm{DAT}}$ clit$_{\mathrm{DAT}}$ yells the boy$_{\mathrm{NOM}}$

Example 1a is a subject-initial sentence, while in 1b the object precedes the subject. However, both sentences mean "*The boy yells at the girl*". Although 1b is a structure where the affected argument linearly precedes the actor, speakers understand in both cases that it is the boy that yells at the girl—and not the other way around—through case marking (the dative pronoun "le"), clitic doubling (coreference between "le" and "la chica"), and the preposition "a", which functions here only as a particle marking an indirect object.

Different verb classes may instantiate alternative hierarchizations for its arguments as well, as shown in the sentences in Example 2:

2a. El chico le teme a la chica.
The boy$_{\mathrm{NOM}}$ clit$_{\mathrm{DAT}}$ fears to the girl$_{\mathrm{DAT}}$
The boy fears the girl.
2b. El chico le gusta a la chica.
The boy$_{\mathrm{NOM}}$ clit$_{\mathrm{DAT}}$ likes to the girl$_{\mathrm{DAT}}$
The girl likes the boy.

While both sentences are syntactically similar, their linking is strikingly different. In Sentence 2a the sentential subject bears the actor macrorole, while in 2b, the subject bears the undergoer macrorole. A consequence of this distinction is that although Spanish is a subject–verb–object (SVO) language (Contreras, 1991; Hernanz & Brucart, 1987; Ocampo, 1995; Suñer, 1982, among others), a sentence like Sentence 2b is considered less acceptable than a sentence like Sentence 3 (see Arnaiz, 1998; Baković, 1998; Contreras, 1976; Gutiérrez-Bravo, 2007; Ordoñez & Treviño, 1999; Zubizarreta, 1998, for some theoretical work and examples on the issue).

3. A la chica le gusta el chico.
The girl$_{\mathrm{DAT}}$ clit$_{\mathrm{DAT}}$ likes the boy$_{\mathrm{NOM}}$
The girl likes the boy.

This inversion of the argument hierarchy is a consistent property of a particular verb class, known as dative object–experiencer psychological verbs (ObjExp psych verbs, hereafter), and has been explained through different theoretical frameworks since Belletti and Rizzi's (1988) theme-marked proposal.

In the present work, we focus on the psycholinguistic implications of the interactions between word order and verb class for syntax-to-semantics linking, to evaluate the interplay between these factors in online processing in Spanish, a language that has not been investigated in this regard. We describe a theoretical account of linking (role and reference grammar) that explains why different verbs may instantiate different unmarked sentential word orders. Finally, experimental predictions for the current study are outlined under the framework of a cross-linguistic model of language processing (extended argument dependency model).

Theoretical considerations

Role and reference grammar

Different linguistic theories have tried to characterize the linking between syntax and semantics (Baker, 1988; Chomsky, 1981; Davis & Koenig, 2000; Dowty, 1991; Fillmore, 1968; Foley & Van Valin, 1984; Gruber, 1965; Jackendoff, 1972, 1987; Perlmutter & Postal, 1984; Saffran, Schwartz, & Marin, 1980; Schwartz, Saffran, & Marin, 1980; Van Valin, 2005, among others). Although there are differences among these accounts, they all share the general assumption that mapping is systematic and constrained by a hierarchy of semantic roles and a hierarchy of syntactic functions. As for the characteristics of semantic/thematic roles, scholars have disagreed considerably as to the precise description of these roles (e.g., regarding their number and conceptual content, and the hierarchical relations holding between them). There have been different proposals to overcome this difficulty. One account assumes that individual semantic roles are subsumed under prototype categories, also called "generalized semantic roles" (GRs). Following role and reference grammar (RRG; Foley & Van Valin, 1984; Van Valin, 2005; Van Valin & Lapolla, 1997), we assume that there are two GRs or *macroroles:* actor and undergoer. Put simply, the linking hypothesis in RRG assumes that the (grammatically relevant) lexical meanings of verbs are represented in logical structures that belong to four aspectual classes. In the case of Spanish, verbs like *gritar* (i.e., "scream") are one-argument activity verbs, represented as in Example 4:

4. **do′** (x) [**scream′**(x)]

In the case of *gritar*, the single argument is mapped into the actor macrorole following the markedness hierarchy from Figure 1.

The unmarked linking relation connects the leftmost argument in this hierarchy to actor and the rightmost argument to the undergoer. The argument of *gritar* corresponds to the "1st argument of do″ (x . . .)" type, which is to the left of the hierarchy and, hence, is linked to actor, as shown in Figure 1. The hierarchy in Figure 1 also shows that actors are mapped into subject position, as with the single argument of *gritar*. In addition, the case assignment rule in Spanish marks the highest ranked macrorole argument to the left with nominative case and the highest ranked macrorole argument to the right with accusative case (Van Valin, 2005, pp. 108–113). More importantly for the current study, Spanish systematically permits the addition of an extra argument to intransitive *verba dicendi* like *gritar* (other verbs of this class are hablar "to talk", gruñir, "to moan", etc.) like in Example 2. Since the verb *gritar* is intransitive, this extra argument is not projected onto a macrorole (i.e., it is a nonmacrorole argument). The case assignment rule determines that nonmacrole arguments get the dative case.

The verb *gustar* ("like") is a two-argument state predicate; its logical structure is represented in Example 5. In terms of individual roles, the first argument is the experiencer, and the second one is the stimulus.

5. **gustar′** (x,y)

This verb—and every object–experiencer dative marking verb—is macrorole intransitive (MI; i.e., only one argument is mapped into a macrorole).

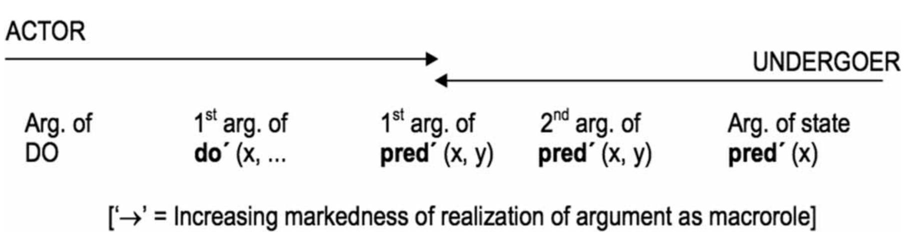

Figure 1. *The actor–undergoer hierarchy (AUH), according to role and reference grammar (Van Valin & LaPolla, 1997). Pred = predicate; Arg. = argument.*

This means that, similar to *gritar*, which takes two arguments, only one argument is mapped into macroroles. Following the hierarchy in Figure 1, the unmarked linking of argument (y) is to the undergoer. No competition for macrorole is involved since there is a single macrorole argument that is projected into the subject position and gets nominative case.

The linking algorithm. The hypothesis that we pursue here accounts for the alternation between SVO and OVS as canonical orders by appealing to the hierarchy in Figure 1 that drives the syntax–semantics interface. RRG describes linking as an algorithm whose order is captured in our representations by a left-to-right sequence. The arguments that qualify to be mapped onto the actor macrorole appear on the left of the thematic role hierarchy. Furthermore, the actor macrorole appears to the left of the undergoer macrorole. Therefore, the actor is selected first by the linking procedure. The SVO order transparently reflects the syntax–semantics linking since actor is linked to subject; this is the case with a typical activity verb like *gritar*. An OVS order for this verb would not transparently show the order in the syntax-to-semantics linking procedure. Thus, we can motivate the choice of SVO as a canonical order for verbs like *gritar*, as shown in Figure 2.

The same reasoning cannot apply to *gustar* since —unlike *gritar*—this verb does not have an actor but an undergoer and, hence, does not involve a typical linking. The highest ranked argument in the actor–undergoer for this verb is a nonmacrorole

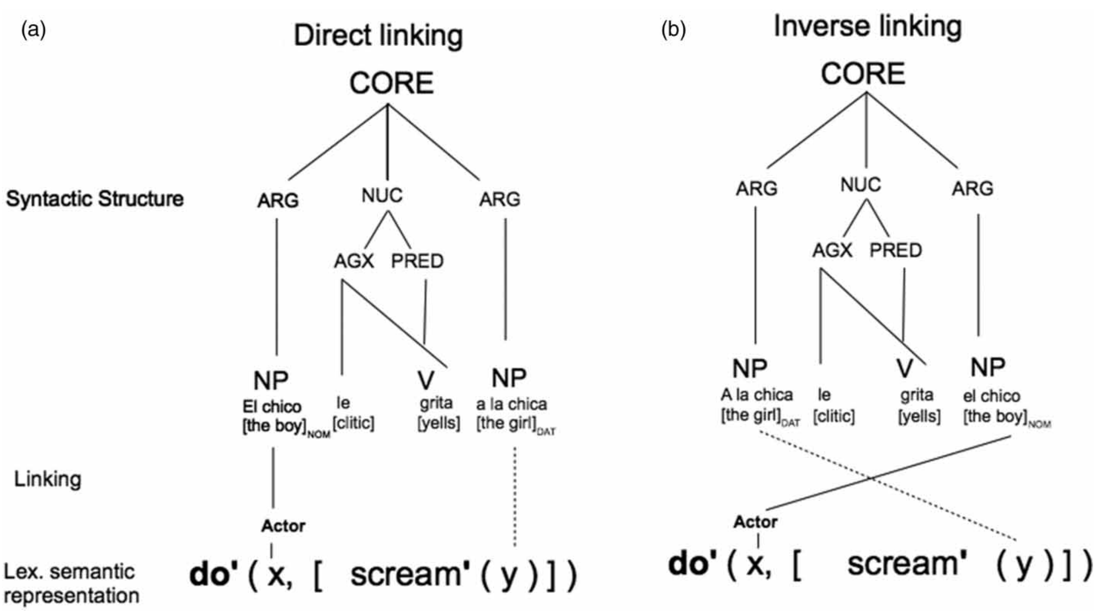

Figure 2. *An illustration of the relationship between syntactic templates and the linking of arguments to generalized semantic roles for sentences with dative-marked activity verbs like "gritar" (*to scream*) according to role and reference grammar (RRG). The subject-initial sentence (a) and the object-initial sentence (b) both draw upon the same syntactic template but nonetheless differ in their interpretation due to differences in linking. While word order (WO) in Sentence A parallels the order in which thematic hierarchy (i.e., "The actor precedes the undergoer", Van Valin & Lapolla, 1997) is linked to the logical structure (LS) of the verb, Sentence B presents a cross-over linking. Note that the dative argument is directly associated with the logical structure of the verb. CORE = the minimal phrase structure domain of the clause within which the nucleus and its arguments are realized; ARG = obligatory argument (noun phrase, NP, or prepositional phrase, PP); NUC = nucleus (essentially equivalent to head, i.e., the element subcategorizing for the arguments); PRED = predicate; V = verb; AGX = agreement index (i.e., dependent on the NUCLEUS, it receives the agreement specifications of all core argument positions present in the logical structure; Belloro, 2004).*

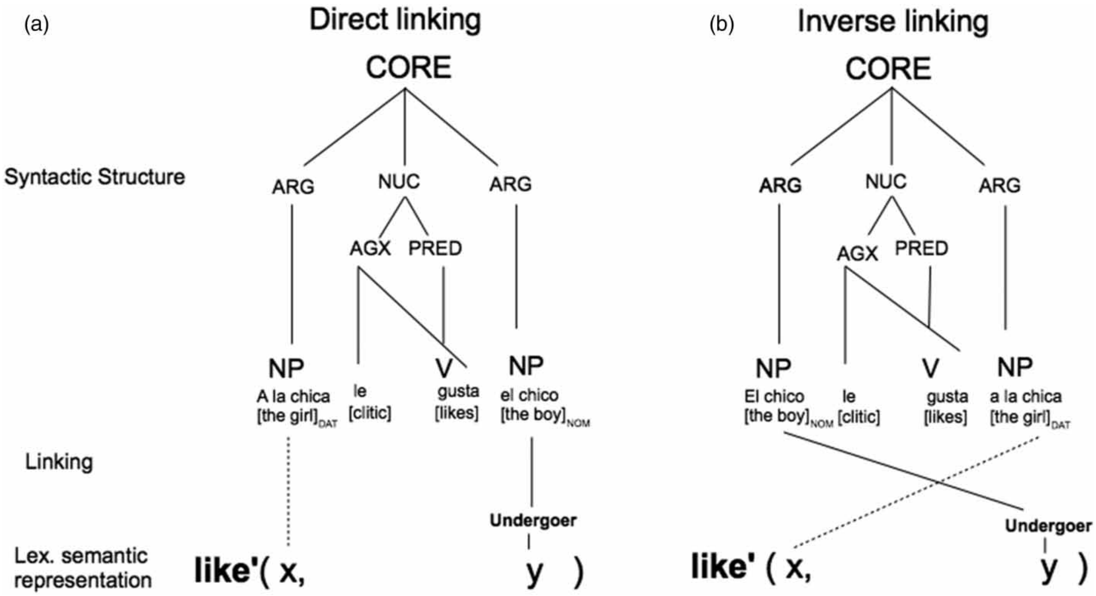

Figure 3. *An illustration of the relationship between syntactic templates and the linking of arguments to generalized semantic roles for sentences with dative-marked psych verbs like "gustar" (*to like*) according to role and reference grammar (RRG). The object-initial sentence (a) and the subject-initial sentence (b) both draw upon the same syntactic template but nonetheless differ in their interpretation due to differences in linking. While word order (WO) in Sentence A parallels the order in which thematic hierarchy (i.e., "The actor precedes the undergoer", Van Valin & Lapolla, 1997) is linked to the logical structure (LS) of the verb, Sentence B presents a cross-over linking. This could account for the unmarkedness of object–verb–subject (OVS) word order in sentences with this type of verb. Note the dative argument is directly associated with the logical structure of the verb. CORE = the minimal phrase structure domain of the clause within which the nucleus and its arguments are realized; ARG = obligatory argument (noun phrase, NP, or prepositional phrase, PP); PRED = predicate; NUC = nucleus (essentially equivalent to head, i.e., the element subcategorizing for the arguments); V = verb; AGX = agreement index (i.e., dependent of the NUCLEUS, it receives the agreement specifications of all core argument positions present in the logical structure; Belloro, 2004).*

argument and therefore cannot be linked to the actor. Instead, the subject, which is typically linked to actor, is the undergoer argument. The consequence of this nontypical linking to the canonical word order is that word order respects the semantic hierarchy and sets the experiencer/nonmacrorole argument first, in spite of the presence of a subject. This accounts for the OVS order of object–experiencer psych verbs like *gustar,* as seen in Figure 3.

In short, these verbs remain faithful to the linking hierarchy at the cost of disobeying the word order generalization respected by most Spanish verbs. The claim is that, in Spanish, WO is sensitive to the thematic hierarchy. We maintain that WO in Spanish complies with the thematic hierarchy at the expense of downgrading an argument's position on the syntactic hierarchy. In the following sections, we explain how this theoretical claim based on RRG motivates the aim of the current psycholinguistic study. Finally, we set the predictions for the current experiment according to the assumptions of the extended argument dependency model (eADM; Bornkessel & Schlesewsky, 2006; Bornkessel-Schlesewsky & Schlesewsky, 2008, 2009).

Objectives of the current study

The objective of our study is to check whether there is any difference in the processing of SVO and OVS orders in Spanish with the assumption that lexical semantics influences structure-building—that is, the processing of word order alternation is sensitive to the semantic class of the verb. The current study represents an attempt to test the psycholinguistic correlates of the interplay between word order and verb type for normal comprehension in Spanish using a self-paced reading task. This has already been investigated in German (Bader & Bayer, 2006; Bornkessel, McElree, Schlesewsky, & Friederici, 2004; Bornkessel, Schlesewsky, & Friederici, 2003; Schlesewsky & Bornkessel, 2003), the results of which have been explained through the extended argument dependency model, a neurocognitive model of cross-linguistic sentence comprehension based on RRG. This model of sentence processing explains how online comprehension of simple core structures (i.e., the verb and its arguments) is achieved cross-linguistically. Work in this framework has focused mostly on verb-final languages (Bornkessel, Schlesewsky, & Friederici, 2002; Frisch & Schlesewsky, 2001, 2005; Roehm, Schlesewsky, Bornkessel, Frisch, & Haider, 2004; Rösler, Pechmann, Streb, Roder, & Hennighausen, 1998; Schlesewsky, Bornkessel, & Frisch, 2003; van den Brink & Hagoort, 2004; among other studies), but has also asked whether evidence from other languages may provide further confirmation of its predictions. Thus, since one of the main purposes of the model is to explain the neurocognitive correlates of processing simple core structures cross-linguistically, we adopt it to generate predictions about processing cost for Spanish sentences. These predictions are addressed in detail in the following section.

The extended argument dependency model

Although the eADM is not the only sentence-processing model that attempts to explain the parsing of sentences with different word orders, we choose it over other models for two reasons: First, since the model aims to separate universal aspects of processing from processing steps (information types) specific to particular languages (Bornkessel & Schlesewsky, 2006, p. 813), it is suited to deriving the qualitative differences between object-initial orders in different sentence types both within a language and across languages. Hence, we believe that this model is more relevant to the question of why canonical word orders vary across verb types within the same language.

Second, alternative models of sentence comprehension test other aspects of language comprehension, and it is not easy to derive hypotheses regarding the interplay between word order and verb type from them. For instance, Frazier and Fodor's (1978) model addresses the mechanism of sentence processing of syntactically ambiguous sentences, or sentences with different types of syntactic complexity (e.g., constituent length or perceptual complexity in centre-embedded sentences). This kind of model would not permit drawing relevant predictions about the role of verb type on processing of simple core structures like the ones being treated in the current paper.

Likewise, memory-based processing models (Gibson, 1998; Lewis & Vasishth, 2005) focus on the relationship between memory load and sentence processing. Memory load is given by the distance between a sentence argument and its head, and processing cost is explained in terms of storage and integration costs (Gibson, 2000) or difficulties at the retrieval of the displaced argument (Lewis & Vasishth, 2005). Once again, these models do not address the question about how simple structures are parsed.

Finally, we report on the results from a behavioural task in this paper. Accordingly, we need a model that also generates predictions for behavioural measures from very simple grammatical sentences. The eADM attempts to relate the neurophysiological evidence that inspired the model (data from event-related potential, ERP, studies, mainly) to behavioural findings, such as the speed–accuracy trade-off (SAT) task (see Bornkessel et al., 2004) or eyetracking measures (Knoeferle, Crocker, Scheepers, & Pickering, 2005; Knoeferle, Habets, Crocker, & Münte, 2005; Scheepers, Hemforth, & Konieczny, 2000) under the assumption that all processing effects observable with behavioural methods should be somehow mirrored in neurophysiological/neuroanatomical data, but not necessarily the other way around. Although we acknowledge that addressing the neurophysiological correlates of this phenomenon is needed to have a better insight of cross-linguistic differences among relatively free word order languages, we leave this question for future research, and we refrain from drawing predictions from models that are developed on the basis of

Table 1. *Summary of competing processing models relevant for the discussion of the current study*

Type of Model	*Model*	*Materials used*	*Type of data that support model*	*Assumptions*	*Predictions on linking and/or word order processing*
Syntax based	Garden-path theory Frazier and Fodor (1978)	Syntactically ambiguous sentences, sentences with different syntactic complexity	Behavioural data	•Parsing is achieved in a two steps process: First, lexical and phrasal nodes are assigned to groups of words within the lexical string that is received. •Second, these structured phrases are combined into a complete phrase marker for the sentence by adding higher nonterminal nodes. •Lexical–semantic processing does not constitute a relevant aspect to the model.	•Ambiguous case marking leads to “subject-first” reading. •Not relevant for disentangling how verb type may influence parsing of nonambiguous grammatical sentences.
Memory based	Dependency locality theory Gibson (1998)	Structures with displaced arguments (subject relative vs. object-extracted relative clauses, centre-embedded structures, etc.), and ambiguous sentences.	Behavioural data	•Distance between an argument and its head increases memory load and difficulty of comprehension. •Memory cost is quantified in terms of the number of syntactic categories that are necessary to complete the current input string as a grammatical sentence. •Lexical–semantic processing does not constitute a relevant aspect to the model.	•Higher RTs for OVS sentences than SVO sentences.

(*Continued overleaf*)

Table 1. *Continued*

Type of Model	*Model*	*Materials used*	*Type of data that support model*	*Assumptions*	*Predictions on linking and/or word order processing*
	Activation-based model Lewis and Vasishth (2005)	Unambiguous and garden-path structures. Double centre embedded structures.	Behavioural and simulation data	•General working-memory processes subserve sentence comprehension. •The processor relies on the ability of retrieval cues to discriminate candidate attachment sites, and in cases where retrieval cues cannot discriminate, the processor relies on activation level. •Retrieval cues are based on syntactic information. •Syntactic and argument structure information as part of a lexical entry that is accessed from declarative memory.	•In OVS sentences, lower RTs in S when additional material is added between O and S. Not relevant for the current study.
Neurocognitive models	Friederici (1999)	Simple core structures and sentences with different syntactic and semantic complexity	Neurophysiological and neuroanatomical data	•Sentence comprehension is assumed to be serial and interactive. The model distinguishes three parsing phases that are related to three time windows involved in syntactic (Phase 1), lexical–semantic/morphosyntactic processing (Phase 2), and integration processes (Phase 3). •As integration of linguistic information occurs at a late stage, the model is not compatible with models that claim immediate or, even, predictive interaction.	•No predictions for behavioural data. •Neurophysiological data are not available for the current study.

Extended argument dependency model Bornkessel and Schlesewsky (2006)	Simple core structures	Neurophysiological, neuroanatomical and behavioural data.	•Sentence processing is serial and interactive. •Similarly to Friederici (1999), the model distinguishes three processing phases. •However, differences in Phases 1 and 2 entail that argument interpretation rests on COMPUTE LINKING step, which in turn depends on both the COMPUTE PROMINENCE and "establish agreement" steps. •Hence, integration of lexical–semantic information is achieved at earlier stages.	•Higher RTs at verb or 2nd argument region when there is a mismatch between prominence relation computed and lexical–semantic structure of main verb.

Notes: Columns show the materials and type of data that support each model, main assumptions regarding processing, and predictions regarding linking and word order processing. RT = reading time; O = object; V = verb; S = subject.

neurophysiological data alone (e.g., Friederici, 1999, 2002). Table 1 shows a description of the main assumptions, predictions, and materials used by the eADM in comparison to other relevant alternative processing models.

Since a full description of the model would go beyond the scope of the current work, we focus on the assumptions that are most relevant to determining how the parser deals with sentences with different word order and verb type (i.e., Phase 2 of the model, as presented in Figure 4). In a nutshell, the eADM posits that: (a) comprehension is achieved through the completion of different stages; it is *serial*; and (b) the processing system does not wait until the end of the sentence to begin interpretation, but rather integrates each element as soon as it is available while predicting upcoming elements; it is *incremental* (e.g., Kamide, 2008; Kutas, DeLong, & Smith, 2011; Van Berkum, Brown, Zwitserlood, Kooijman, & Hagoort, 2005; Wicha, Moreno, & Kutas, 2004). Unlike other serial models of sentence processing (Frazier & Fodor, 1978; Friederici, 1999, 2002), prediction for the eADM involves generating not only expectations for syntactic structures but their semantic interpretation as well. Even in the absence of verbal information, arguments are assigned a generalized semantic role ("actor" or "undergoer") in accordance with their relative prominence (COMPUTE PROMINENCE step). Prominence is the information used to construct an interpretive hierarchy between the arguments of a sentence; prominence assignments are based both on morphosyntactic information (morphological case and argument position) and on a small set of cross-linguistically motivated, hierarchically structured features (e.g., animacy and definiteness).

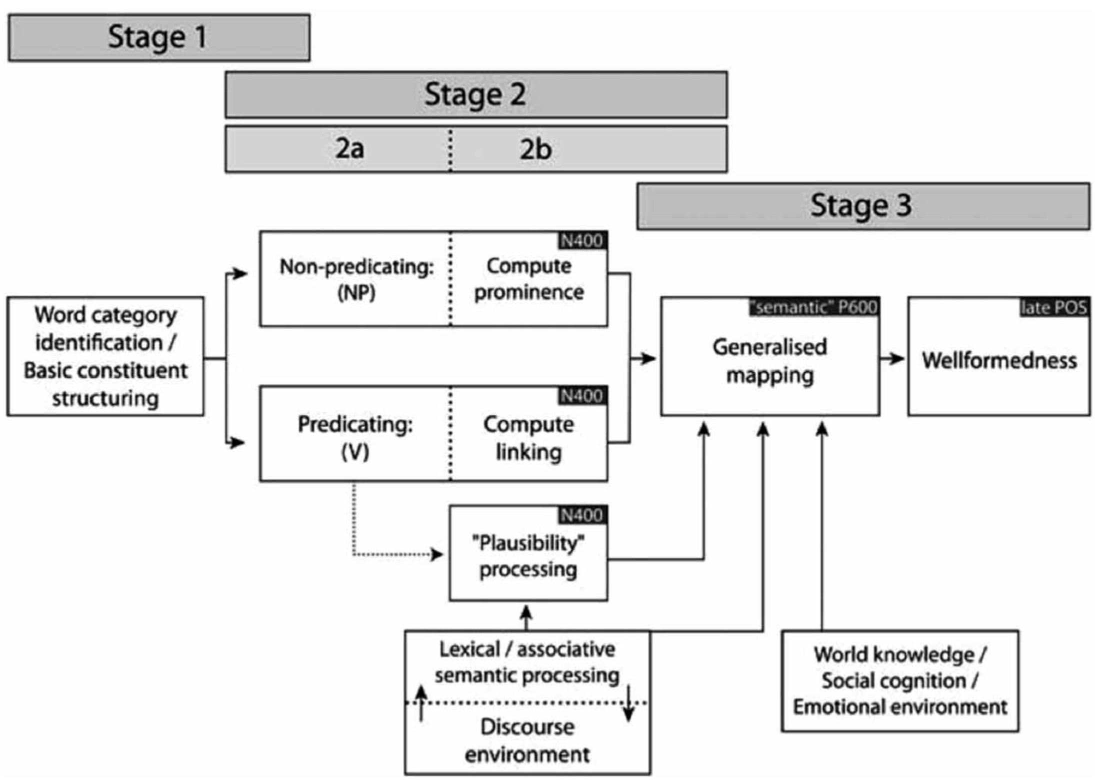

Figure 4. *The architecture of the latest version of the extended argument dependency model (eADM; Bornkessel-Schlesewsky & Schlesewsky, 2008).*

As for verbs, their processing requires that the verb's lexical argument representation (its logical structure, LS) is associated with the arguments that have already been processed by using previously computed prominence relations, agreement, and voice (active, passive; COMPUTE LINKING; Bornkessel & Schlesewsky, 2006). Another characteristic of the eADM is that it assumes that the processing system follows a "least effort" principle, also referred to as "minimality". This principle is based on the idea that the parser assumes the simplest possible structure and interpretation compatible with the input that has appeared so far, thus providing predictions for processing of ambiguously case-marked arguments. Finally, with regard to ongoing role assignment, the model posits an advantage for interpreting the nominative argument as the highest role of the hierarchy (actor; Bornkessel-Schlesewsky & Schlesewsky, 2009).

Notice that this model conceptualizes parsing as an interactive process: Parsing is first guided by syntactic constraints (every word of a sentence triggers a series of syntactic template activations), but rapidly turns to information from argument hierarchization, provided by both morphosyntactic and language-specific animacy and definiteness features, to compute prominence features and generate expectations about the possible words to come.

Hypotheses and predictions

We focus on how predictive and integrative processes during incremental interpretation are influenced by word order and verb type in Spanish, and whether parsing costs are consistent with the theoretical assumptions about linking depicted by RRG.

We now turn to the hypotheses for the present experiment. Our experiment uses three critical regions: the first noun phrase (NP), the verb (V), and the second NP. The predictions formulated for these positions on the basis of the eADM are discussed in turn.

Spanish allows multiple WOs so, according to the eADM, processing demands should not differ significantly when reading an initial nominative or dative-marked sentence argument. Conversely, easier processing for nominative would support the idea that, at early stages, argument hierarchization does not provide sufficient relevant information to form expectations about syntax-to-semantics linking.

The model makes its strongest predictions at the verb region, since it posits that syntactic and semantic integration of the verbal information is achieved after the prominence of the previous arguments is computed. The model predicts that a reanalysis of argument hierarchization should take place if there is a mismatch between the prominence assigned to the first argument and the requirements of the verb's lexical representation. In other words, additional processing cost is expected once the verb is encountered in the (B) sentences from Figures 2 and 3. Comprehension is predicted to show no extra difficulty in those cases where the COMPUTE PROMINENCE step parallels the argument's position in the verb's LS, as in the (A) sentences from these figures.

Finally, the model predicts that, once the verb is encountered, the cost of reaching the final interpretation will also depend on which of the two GRs is assigned to the nominative-marked argument (Bornkessel & Schlesewsky, 2006, p. 802). Sentences with verbs that assign "actor" to the nominative argument (activity verbs) should be easier to process than the ones that assign "undergoer" to it (ObjExp psych verbs with dative).

EXPERIMENTAL STUDY 1

Method

Participants

Seventy-seven native speakers of Argentinean Spanish (49 females) participated in the experiment voluntarily. Subjects ranged in age from 18 to 54 years old ($M = 31.6$ years old). None of the subjects had a history of prior neurological disease, drug or alcohol abuse, psychiatric disorders, developmental speech/language disorders, or learning disabilities.

Table 2. *Mean values, standard errors,* t*-scores, and* p*-values for frequency, length, imageability, and concreteness of the two groups of nouns chosen for the current self-paced reading task*

Variable	*Group*	N	*Mean*	SE	t	p*-value*
Frequency	NP1	24	87.8	31.7	0.293	.771
	NP2	24	75.8	25.9		
Length	NP1	24	7.4	0.4	0.379	.707
	NP2	24	7.2	0.4		
Imageability	NP1	24	5.8	0.1	−0.167	.868
	NP2	24	5.9	0.1		
Concreteness	NP1	24	5.7	0.1	0.126	.738
	NP2	24	5.6	0.2		

Note: NP = noun phrase.

All participants had normal or corrected-to-normal vision. All of them provided written consent prior to the study.

Stimuli

Four critical sentence conditions were created following a 2 × 2 factorial design that manipulated verb type (psych verb vs. activity verb) and word order (SVO vs. OVS). For the critical sentences, 24 psych verbs that require dative case and assign the role of experiencer to the object (ObjExp PsychV) were selected. In addition, 24 activity verbs that also assign dative case to the second argument (SubjAct V) were chosen. The two groups of verbs were matched in length (psych verbs, $M = 6.54$, $SE = 0.23$; activity verbs, $M = 6.5$, $SE = 0.22$) according to the LEXESP database (Davis & Perea, 2005). An independent-samples t-test showed no significant differences between groups, $t(46) = 0.129$, $p > .05$. However, activity verbs were significantly more frequent ($M = 21.04$, $SE = 8.76$) than psych verbs ($M = 2.7$, $SE = 0.76$), $t(46) = -2.08$, $p < .05$. For this reason, verb frequency was used as a fixed factor for the analysis of the data from the verb region onwards (see the *Statistical Analysis* section for more details).

Verbs were placed in semantically reversible sentence frames, resulting in 48 stimuli sentences for each group of verbs. The frames consisted of 24 noun phrases (NPs) formed by a determiner (det) + noun (N) and 24 prepositional phrases (PP) consisting of preposition "a" + det + N. The NP and the PP functioned as the subject and the object of these verbs, respectively. We counterbalanced the gender of the nouns used for the NPs and the PPs, and they were matched according to the same database so that they did not differ significantly in frequency, length, imageability, and concreteness between the verb type conditions. Table 2 shows the mean, standard errors, t-scores and p-values for frequency, length, imageability, and concreteness of the two groups of nouns. Finally, we kept animacy constant in both subject and object constituents and formulated questions so that participants were forced to do thematic role assignment to respond accurately. This way, we avoided participants basing their answers to the comprehension task on factors other than lexical properties of the verb.

In order to avoid "wrap-up effects" (Just & Carpenter, 1980), an additional prepositional phrase (PP), adverbial phrase (AdvP), or complementizer phrase (CP) was added at the end of the sentence. These additional phrases could be attached to both NPs when placed after the verb, and they were semantically neutral, so that they did not facilitate any semantic interpretation other than the one provided by the role assignment required by the verb. A sample set of experimental conditions can be seen in Table 3. The 96 resulting stimuli were first checked by two native speakers of Spanish, and stimuli that were considered odd were modified. Apart from this, an acceptability judgement task was run in order to disentangle whether results of the comprehension task were biased by sentence

Table 3. *Critical sentences for the current self-paced reading task*

Condition	*Sentence*
(a) *Object–experiencer psych verb SVO*	La maestra le gusta a la cocinera de la escuela pública. The teacher DAT$_i$ likes to the cook$_i$ of the school public. *The cook of the public school likes the teacher.*
(b) *Object–experiencer psych verb OVS*	A la cocinera le gusta la maestra de la escuela pública. To the cook$_i$ DAT$_i$ likes the teacher of the school public. *The cook likes the teacher of the public school.*
(c) *Subject act. verb SVO*	La maestra le grita a la cocinera de la escuela pública. The teacher DAT$_i$ yells to the cook$_i$ of the school public. *The teacher yells at the cook of the public school.*
(d) *Subject act. verb OVS*	A la cocinera le grita la maestra de la escuela pública. To the cook$_i$ DAT$_i$ yells the teacher of the school public. *The teacher of the public school yells at the cook.*

Note: O = object; V = verb; S = subject; psych = psychological; act. = activity.

acceptability (see the *Acceptability Judgement Task* section).

In addition, a set of six practice trials and 100 filler sentences were created. They contained different syntactic complexity and length from the critical trials, although 25 of them included other types of verbs that required dative constructions so that the participants could not become familiar to what was being tested. The complete list of critical sentences may be found in Supplemental Material A.

Finally, one question for each practice item, critical trial, and filler sentence was prepared to test comprehension. The questions were formulated in such way that the participants had to judge whether a question correctly described the content of the preceding experimental sentence or not. Half of the questions required the answer "yes", and half of them required the answer "no". In the case of critical items, half of the questions involved the subject of the sentence, and half of them asked about the object. Table 4 shows examples of these questions.

Procedure

Participants were tested individually in a well-lit and quiet place. Sentences were presented on a 15.4" Hewlett Packard laptop screen using the Linger software (developed by Rohde, 2001). All the critical sentences were presented on a single line, using the self-paced word-by-word moving window paradigm (Just, Carpenter, & Wooley, 1982). After the participants read the last word of the sentence, the comprehension task question appeared on the centre of the screen. Participants were told to answer "yes" or "no" by pressing "F" or "J", respectively. In cases where an incorrect answer was given, the message "Oops. Respuesta incorrecta" ("Oops. Incorrect answer") appeared on the centre of the screen. The task was explained to participants, and six practice sentences were provided in order to ensure that they understood the task. They were asked to read sentences at a natural pace and to answer the questions that followed them as accurately and fast as possible. In cases where they made a mistake in one of the questions, they were asked to read more carefully.

Sentences were distributed according to a Latin square design, so each participant would only see one of the four conditions of the 24 sets of sentences. This means that they only read 24 of the 96 critical sentences, and six sentences of each of the four conditions. Presentation of critical items and fillers was randomized for each participant. Experimental sessions lasted between 20 and 30 min. After the experiment was done, participants were asked whether they could figure out what was being tested and whether they had developed any strategy to answer the comprehension task

Table 4. *Example of questions with affirmative answer used for the critical items in the sentence comprehension task*

Critical sentences	*Question*
ObjExp psych verb	Question about the subject
(SVO) La abuela le apena a la bailarina de vestido blanco.	¿Es la abuela por quien se sienten mal?
The dancer in white dress feels sorry for the granny	*Is the granny for whom someone feels sorry?*
(OVS) A la bailarina le apena la abuela de vestido blanco	
The dancer feels sorry for the granny in white dress	
Activity verb	
(SVO) La abuela le ruega a la bailarina de vestido blanco	¿Es la abuela quien pide algo?
The granny begs the dancer in white dress	*Is the granny who asks for something?*
(OVS) A la bailarina le ruega la abuela de vestido blanco	
The granny in white dress begs the dancer	
ObjExp psych verb	Question about the object
(SVO) El ladrón le disgusta a la policía que lleva gorro negro.	¿Es la policía quien está irritada?
The policewoman that wears a black cap dislikes the thief.	*Is the policewoman who is upset?*
(OVS) A la policía le disgusta el ladrón que lleva gorro negro.	
The policewoman dislikes the thief that wears a black cap.	
Activity verb	
(SVO) El ladrón le dispara a la policía que lleva gorro negro.	¿Es la policía el blanco del disparo?
The thief shoots the policewoman that wears a black cap.	*Is the policewoman the target of the shoot?*
(OVS) A la policía le dispara el ladrón que lleva gorro negro.	
The thief that wears a black cap shoots the policewoman.	

Note: ObjExp = object–experiencer; psych = psychological; O = object; V = verb; S = subject.

questions. Only one participant declared that he had tried to identify the subject and the object of the sentence in order to reply accurately, and his results were discarded from the analysis, and a new participant was tested in his place. Thus, the analysis was performed on 76 participants.

Statistical analysis

The results of five participants were taken out because their accuracy rate was beneath 70%, and the results from three more participants were ruled out in order to make the amount of data per condition even. Thus, the data from 68 participants (17 participants per list) were considered for the current analysis.

A linear mixed-effects (LME) model was fitted to the data, with verb type and word order as fixed factors and items and subjects as random factors. According to Baayen and Milin (2010), the advantage of LME models over repeated measure analyses of variance (ANOVAs) is that variance by item and by participant may be taken into account simultaneously. In this way, LME models allow researchers to model the individual response of a given subject to a given item. Besides, a maximal random-effects structure was included, as linear mixed-effects models that do not consider random intercepts and slopes involve the risk of Type I error inflation (Barr, Levy, Scheepers, & Tily, 2013).

In this model, both independent variables were dichotomous, so psych verbs were coded as 1, and activity verbs were coded as −1. Sentences with canonical WO were coded as −1, and sentences with noncanonical WO were coded as 1. By using this orthogonal contrast, in the outcome we can see how much of the variance in reading times can be predicted by each of the independent variables and by the interaction of both of them.

After examining the data set, residuals (i.e., deviations of the observations from the sample mean) exceeding 2.5 standard deviations were eliminated, in order to avoid an effect of extreme responses. In all cases, trimming improved the model at a level of $\alpha = .05$. In the comprehension task, we removed 30 observations in the accuracy analysis and 26 in the reaction time analysis, or

1.83% and 1.59% of the total observations, respectively. For the self-paced reading task, we removed a mean of 41 observations per region, or 2.51% of total observations.

For the analysis of reading and response times, raw reading times were transformed to log-normal values, as raw time measures may lead to incorrect conclusions because of the non-normality of distribution of its residuals (see Baayen & Milin, 2010, for a discussion on the issue). Reading times are reported in milliseconds.

The regions used for the analysis of the self-paced reading task consisted of single words except for the region corresponding to the prep + det, in which the mean reading times (RTs) of the preposition (prep) and the determiner were summed and averaged for feminine nouns. For masculine nouns, the preposition "a" contracts with the masculine determiner "el", for phonological reasons, yielding "al". Thus, the masculine items consisted of one word in the prep + det region, and the feminine equivalent consisted of two words: "a" (preposition) "la" (feminine determiner).

As word order variation is noticeable from the first word of the sentence with preposition "a", the analysis of word reading times was performed from Region 1 onwards. For SVO conditions, these regions comprised: (1) det; (2) subject noun; (3) dative clitic; (4) verb; (5) prep + det; (6) object noun; (7) and (8) prepositional phrase. For OVS conditions, the regions are: (1) prep + det; (2) object noun; (3) clitic; (4) verb; (5) det; (6) subject noun; (7) and (8) prepositional phrase. Regions of interest for the analysis of verb type included Regions 4, 5, and 6. Reading times for Regions 7 and 8 were analysed to control for possible spillover effects.

For the self-paced reading task, LME models only included fixed factors that were relevant for each region. This means that from Regions 1 to 3, only word order was included. Region 4 onwards included verb type as a fixed factor as well. Control predictors such as age (all regions) and log-normal values of noun (Regions 2 and 5) and verb frequency (Region 4) were included as well. Random slopes and intercepts for these predictors were not included in the model because fitting their random effects, plus correlation terms, would require a larger data set to be able to estimate all the effects reliably.

Finally, when models with maximal random effects failed to converge, random effects were taken out in the following order: random slope of interaction between verb type and word order (Regions 5 and 7) and within-items random intercepts. According to Barr et al. (2013), this is the desirable order in which random factors should be excluded to prevent overall Type I error when using LME models.

The results of the current experiment are presented as coefficient, estimates, their standard errors, t-scores, and z-scores (for generalized linear mixed-effects models). An absolute t-score or z-score of 2 or greater is equivalent to a level of significance of $a = .05$ (see Baayen, 2008, for detailed alternatives to estimate significance in linear mixed-effects models).

Results

Comprehension task

Question accuracy. Mean accuracy for all comprehension questions was 84.33%. This indicates that participants were paying attention to the content of the sentences. Mean accuracy of critical sentences was 75.92%. Figure 5a shows mean accuracy according to condition. Differences in accuracy according to verb type and word order were analysed with a generalized linear mixed-effects model. The analysis revealed a significant effect of word order. On average, participants responded more accurately when sentences were in noncanonical WO ($M = 79.04\%$) than when they were in SVO word order ($M = 72.79\%$): coefficient = 0.4986, $SE = 0.2053$, $z = 2.428$. An interaction between verb type and word order was found. Comprehension questions for sentences with psych verbs were answered more accurately when the sentences were OVS (88.72%) than when they were SVO (60.78%). On the other hand, comprehension questions for activity verb sentences were answered more accurately with SVO word order (84.80%) than with OVS word order (69.36%):

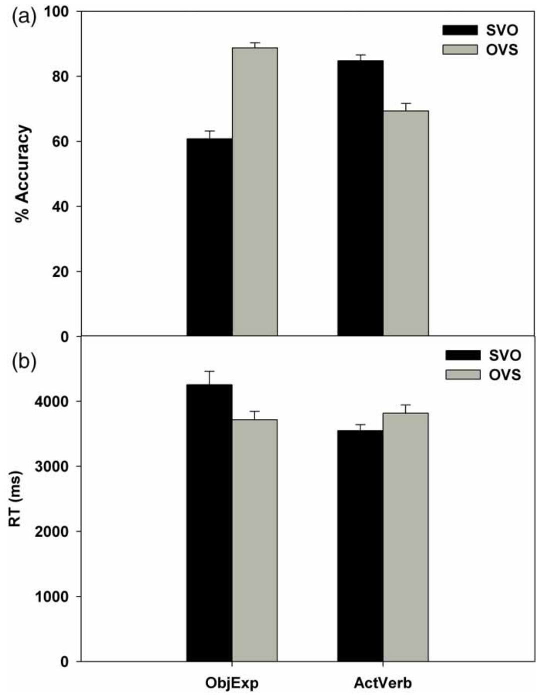

Figure 5. *(a) Mean percentage of correct answers (±SE) and (b) mean response times (RTs; ±SE) for the sentence comprehension task in the current self-paced reading task according to condition. SVO = subject–verb–object; OVS = object–verb–subject.*

coefficient = 1.6804, $SE = 0.1952$, $z = 8.610$, $p < .001$.

Response times. Figure 5b shows mean response times according to condition. Analyses of differences in response times between verb type and word order reveal that there were no effects of verb type or word order. Interactions between both factors were marginally significant: coefficient = −0.022121, $SE = 0.010499$, $t = -1.95$. Tukey post hoc test reveals that participants answered comprehension questions for psych verb sentences significantly faster with OVS word order ($M = 3716$ ms) than with SVO word order ($M = 4254$ ms): coefficient = 0.05723, $SE = 0.02716$, $t = 2.107$. However, this difference between OVS and SVO sentences was not significant for comprehension questions for activity verb sentences: coefficient = −0.02462, $SE = 0.02949$, $t = -0.835$.

Self-paced reading task reading times

Mean reading times and standard error bars at all regions are summarized in Figure 6. For the sake of clarity, in this section we only discuss the main effects encountered in each region and their direction, and we include the outcome of all the fixed factors included in the mixed-effects model analysis from all regions in Table 1 from Supplemental Material B.

The first region showed no effects of word order, although reading times were affected by age of participants, indicating that the older the participant, the longer the RTs for that region: coefficient = 0.007117, $SE = 0.002926$, $t = 2.43$.

Reading time of Region 2 was affected by noun frequency. This region was read significantly faster when noun frequency was higher: coefficient = −0.0260680, $SE = 0.0065505$, $t = -3.98$. Regions 3 and 4 showed no significant effects of word order, noun frequency, verb type (Region 4), or age.

Region 5 (prep + det/det) revealed no significant effect of verb type or word order. However, an interaction between verb type and word order was found: coefficient = −0.0554586, $SE = 0.0067150$, $t = -8.26$. A Tukey HSD post hoc test revealed

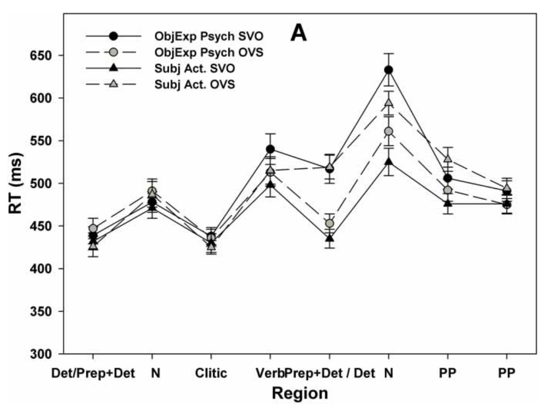

Figure 6. *Mean reading times and standard error bars for the four conditions of the self-paced reading task in the current self-paced reading task. This figure shows mean reading time (RT) for the reduced data set. ObjExp = object–experiencer; psych = psychological; subj = subject; act. = activity; det = determiner; N = noun; PP = preposition phrase; SVO = subject–verb–object; OVS = object–verb–subject. See main text for details.*

that reading times for sentences with psych verbs were significantly higher for SVO sentences ($M = 517$ ms) than for OVS ones ($M = 453$ ms): coefficient = 0.11204, $SE = 0.02354$, $z = 4.760$. Conversely, for sentences with activity verbs, reading times were lower for SVO sentences ($M = 435$ ms) than for OVS ones ($M = 519$ ms): coefficient = −0.10382, $SE = 0.02356$, $z = -4.407$.

Region 6 (object/subject noun) showed a main effect of verb type: coefficient = 0.0311448, $SE = 0.0150044$, $t = 2.08$. On average, reading times for words in this region were lower when words belonged to sentences with activity verbs ($M = 559$ ms) than when they belonged to sentences with psych verbs ($M = 597$ ms). An interaction between verb type and word order is also present in this region: coefficient = −0.0712946, $SE = 0.0096325$, $t = -7.40$. A Tukey HSD post hoc test revealed that reading times in sentences with psych verbs were significantly higher for SVO sentences ($M = 633$ ms) than for OVS ones ($M = 561$ ms), coefficient = 0.16927, $SE = 0.06089$, $z = 2.78$. On the other hand, for sentences with activity verbs, reading times were lower for SVO sentences ($M = 525$ ms) than for OVS ones ($M = 594$ ms): coefficient = −0.11788, $SE = 0.04807$, $z = -2.452$.

A similar interaction was found at Region 7 (PP): coefficient = −0.0308209, $SE = 0.0072127$, $t = -4.27$. Tukey HSD post hoc test showed that in sentences with activity verbs, reading times were significantly lower for SVO sentences ($M = 476$ ms) than for OVS ones ($M = 494$ ms): coefficient = –0.08503, $SE = 0.02420$, $z = -3.514$. However in sentences with psych verbs, differences in reading times were not significant. Reading times were marginally lower for SVO sentences ($M = 506$ ms) than for OVS ones ($M = 492$ ms): coefficient = −0.0806, $SE = 0.02414$, $z = 1.577$.

Reading times from Region 8 showed an interaction between verb and word order, coefficient = −0.0140845, $SE = 0.0067407$, $z = -2.09$. Nevertheless, the interaction was not confirmed by Tukey's post hoc test. Differences in reading times between OVS and SVO conditions of each verb type were not significant (psych verbs: coefficient = 0.025629, $SE = 0.019550$, $z = 1.311$; activity verbs: coefficient = −0.029068, $SE = 0.019609$, $z = -1.482$).

EXPERIMENTAL STUDY 2

Acceptability judgement task

All 96 stimuli and 100 filler sentences were used in an acceptability judgement task in order to disentangle whether difficulty for understanding SVO sentences with psych verbs and OVS sentences with activity verbs was related to sentence acceptability. Twenty of the filler sentences were modified so that they would become unacceptable sentences in the language, and the syntactic constituents of 20 other filler sentences were scrambled so that they would become acceptable but not very common sentences of the language. In this way, we increased the variability of acceptability of all sentences so that participants were forced to think about their response.

Method

Participants

Sixty-one speakers of Spanish from Argentina (38 females) participated in this experiment voluntarily. Age ranged from 18 to 55 years old ($M = 32.8$ years old). None of the subjects had a history of prior neurological disease, drug or alcohol abuse, psychiatric disorders, developmental speech/language disorders, or learning disabilities. All participants had normal or corrected-to-normal vision. All of them provided written consent prior to the study.

Procedure

Participants were tested individually through the Ibex Farm application (developed by Alex Drummond, McGill University, http://spellout.net/ibexfarm). Trials were presented randomly according to a Latin square design. Thus, each participant saw 24 critical sentences, six sentences per condition. Participants were asked to judge on a 5-point scale how the sentence they had just read sounded to them. They were reminded that their answer should be driven according to whether they found the sentence acceptable (5 points), fairly acceptable (4), not that acceptable (3 points), doubtfully acceptable or unlikely to be acceptable (2 points), or not an acceptable sentence of Spanish (1 point). Although no time limit was set for each of the trials, participants were encouraged to rate sentences as fast as possible and to base their answers on their own intuition.

Statistical analysis

Mean acceptability was computed for each critical item, and seven items from each condition that were matched on mean acceptability were chosen in order to re-run statistical analysis of the comprehension task. An ANOVA revealed no difference between the four groups of sentences, $F(3) = 0.002$, $p > .09$. Table 5 shows mean acceptability and standard error for the sentences selected from each condition.

Table 5. *Mean acceptability and standard error of the sentences selected for the reanalysis of the data of the current self-paced reading experiment*

Verb type	*Word order*	*Verb*	*Mean acceptability*	SE
ObjExp	SVO	apenar	2.17	1.47
		repugnar	3.67	1.52
		importar	3.4	1.67
		intrigar	3	0.7
		convencer	3.38	1.4
		interesar	3.2	0.45
		aturdir	2.71	1.25
ObjExp	OVS	asustar	4	0.87
		enfermar	2.29	1.38
		fascinar	2.64	1.45
		importar	3.38	0.92
		enojar	2.71	1.5
		convencer	2.43	1.45
		interesar	4	1.31
Activity	SVO	cocinar	3.4	1.14
		suspirar	3.78	1.2
		suplicar	2.86	1.34
		protestar	3.8	1.64
		cobrar	3	1.58
		aconsejar	2	1.41
		enseñar	2.75	1.16
Activity	OVS	hablar	3.33	1.03
		gritar	3.17	1.47
		susurrar	2.75	0.5
		cocinar	2.75	1.5
		conivdar	2.71	1.38
		disparar	3.14	1.34
		avisar	3.75	1.03

Note: ObjExp = object–experiencer; O = object; V = verb; S = subject.

Results

Question accuracy

Statistical analysis on accuracy and response time on this subset of 28 items was similar to the one applied for all 96 critical sentences. Results show that mean accuracy for all critical items was 74.71%. Analyses of differences in accuracy according to verb type and word order revealed no main effects of word order or verb type. However, an interaction between verb type and word order was found. Comprehension questions for psych verb sentences were answered more accurately with OVS word order (83.20%) than with SVO word order (63.23%). On the other hand, comprehension questions for activity verb sentences were answered more accurately after reading sentences with SVO word order (82.22%) than with OVS word order (70.45%): coefficient = 0.8438 $SE = 0.2080$, $z = 4.057$, $p < .001$.

Response times

Analyses of differences in response times between verb type and word order reveal a main effect of word order. The interaction between both factors was marginally significant: coefficient = −0.022121, $SE = 0.010499$, $t = -1.95$. Tukey post hoc test reveals that this difference responded to the high response time driven by questions about SVO sentences with psych verbs ($M = 4590$ ms) in comparison to the other three conditions (psych OVS: 3754 ms, coefficient = 0.132762, $SE = 0.051751$, $t = 2.470$; activity SVO: 3634 ms, coefficient = 0.083098, $SE = 0.044898$, $t = 1.851$; Activity OVS: 3631 ms, coefficient = 0.132762, $SE = 0.048976$, $t = 2.711$).

All in all, reanalysis of the subset of 28 critical sentences matched in acceptability show identical results in terms of accuracy of the analysis of the total data, while differences in response times are minimized in almost every condition except for comprehension questions for SVO sentences with psych verbs, showing that even when considering a lower amount of data, there is still difficulty in answering comprehension questions for these sentences.

Discussion

In the current study, comprehension of sentences with alternative WO in Spanish (SVO and OVS) was tested by means of a word-by-word self-paced reading and comprehension task. Psycholinguistic evidence on WO alternation and sentence processing in languages such as English (Beretta & Campbell, 2001; Corrigan, 1988; Ferreira, 1994, Piñango, 2006; Thompson & Lee, 2009) and German (Bornkessel et al., 2002, 2003, 2004, 2005; Kretzschmar, Bornkessel-Schlesewsky, Staub, Roehm, & Schlesewsky, 2012; Schlesewsky & Bornkessel, 2006, among others) has shown that there is a complex interaction between word order and verb type that modulates processing cost and neural activation.

The cognitive consequences of word order and verb type interactions in Spanish have previously only been examined with agrammatic aphasics (Beretta, Harford, Patterson, & Piñango, 1996; Beretta et al., 2001). Dative-marked object–experiencer psych verbs are useful for testing (a) how the predictive and integrative mechanisms in language processing are influenced by word order and verb type; and (b) whether these mechanisms can be related to theoretical accounts that assume different underlying word order for different types of verbs.

Three main results were found: First, there was an interaction between verb type and word order in the regions that followed the verb of the sentence. Second, a main effect of verb type was found in the postverbal region. Finally, a main effect of word order and an interaction between verb type and word order were present in comprehension question accuracy. These three findings are successively discussed in the light of results from previous studies and eADM.

WO variation has direct consequences on the processing of syntax-to-semantics linking. The linear order of constituents determines the sequence of an event's participants in the utterance. Our results show that, in Spanish, WO variation systematically interacts with the class of the verb involved in the event in both online and offline comprehension processes. The online results reveal that readers slowed down when they encountered a psychological verb after a nominative argument. The same behaviour took place when they found an activity verb after a dative argument, thus confirming what has been established as the "unmarked" WO for declarative sentences containing both activity (SVO) and object–experiencer verbs (OVS; Arnaiz, 1998; Baković, 1998; Contreras, 1976; Gutiérrez-Bravo, 2007; Ordoñez & Treviño, 1999; Zubizarreta, 1998).

In accordance with Bornkessel et al. (2003), we believe that the modulation of reading times cannot have a merely syntactic explanation. The fact that verb type/word order interaction only appeared once the verb was read signals that differences in reading times must take place due to a lexically motivated reanalysis. Following the eADM, this reanalysis occurs due to the mismatch between the prominence assignment to the first argument (COMPUTE PROMINENCE) and the verb's lexical argument representation (COMPUTE LINKING). This model assumes that language processing is incremental. Predictions about upcoming words are generated by the interaction between syntactic (case, argument position) and semantic (argument hierarchization) information according to language-specific constraints.

Let us exemplify this with the sentences used in this study: As the reader finds an NP, a set of syntactic templates is activated in Phase 1. In Phase 2, prominence is computed according to morphosyntactic information such as case (nominative), argument position (first argument), and hierarchized information such as animacy (+ animate) and definiteness (+ definite). The result of this computation is compatible with the role of "actor"; thus the parser expects a verb whose lexical semantic structure takes an "actor" as a first argument (i.e., an activity verb). If the following verb is an activity verb (e.g., *gritar*), reading continues without any higher processing cost. In contrast, if a psych verb

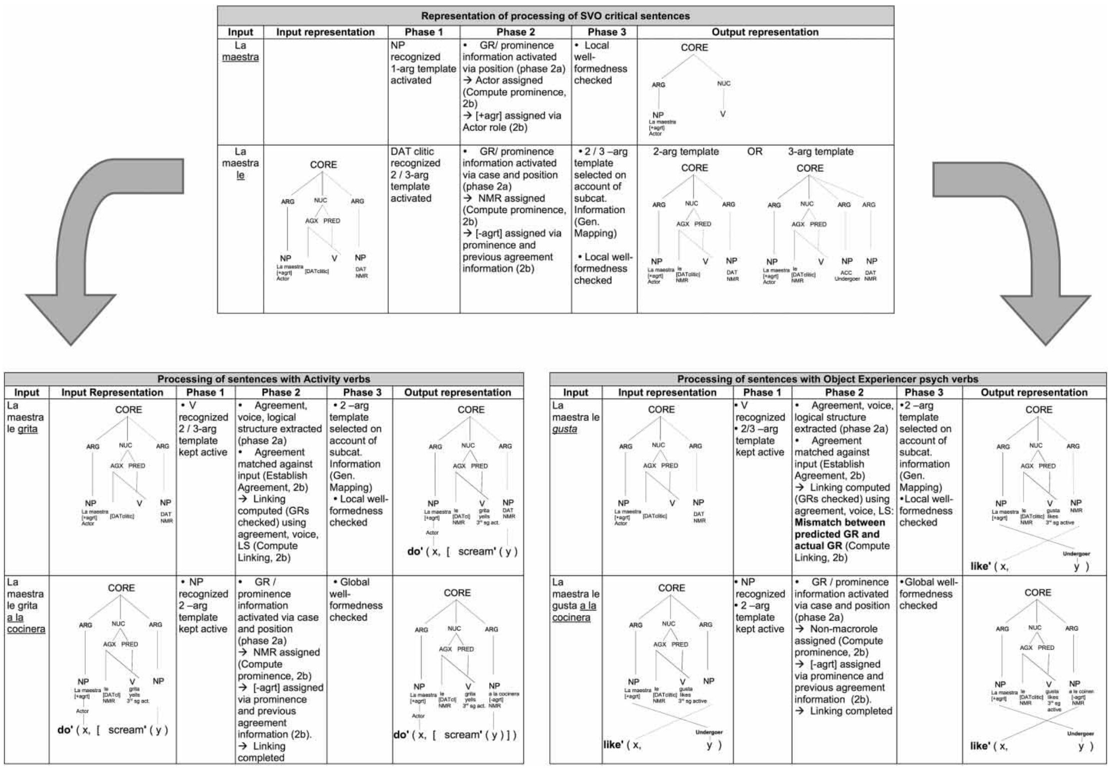

Figure 7. *Summary of the incremental processing steps involved in the comprehension of the subject–verb–object (SVO) sentences used in the current experiment adapted from Bornkessel and Schlesewsky (2006). Lower tables show the processing steps at the disambiguation region of the verb: activity verbs (left) and object–experiencer psychological (psych) verbs (right). CORE = the minimal phrase structure domain of the clause within which the nucleus and its arguments are realized; ARG = obligatory argument (noun phrase, NP, or prepositional phrase); NUC = nucleus (essentially equivalent to head, i.e., the element subcategorizing for the arguments); V = verb; AGX = agreement index (i.e., dependent of the NUCLEUS, it receives the agreement specifications of all core argument positions present in the logical structure); DAT = dative; NMR = nonmacrorole; arg = argument; agrt = agreement; gen = general; 3sg = third person singular. © 2006 by the American Psychological Association. Adapted with permission (Bornkessel and Schlesewsky, 2006).*

appears (e.g., *gustar*), the reader needs to revise the previous argument hierarchization and assign a new macrorole that matches the constraints imposed by the lexical–semantic structure of the verb (i.e., "undergoer"). This process is exemplified in Figure 7.

When an initial object takes place the process is similar. However, the eADM model assumes that dative objects are nonmacrorole arguments, which are directly linked to the lexical–semantic structure of the verb. Spanish dative constructions allow for two possible interpretations for the missing nominative argument: It is either the "actor" of a sentence with an activity verb, or the "undergoer" of a sentence with an object–experiencer verb. By choosing the second option, the parser hypothesizes that the sentence contains a direct linking between the nonmacrorole argument and the lexical–semantic structure of the verb and predicts a psych verb. If this is the case, comprehension continues flawlessly. If an activity verb appears, the nonmacrorole argument is linked to the second argument of the LS structure of the verb, and a new macrorole ("actor") is predicted for the last nominative argument. This is shown in Figure 8.

This explanation is compatible with cross-linguistic evidence suggesting that the parser tries to avoid a violation of the thematic hierarchy even if

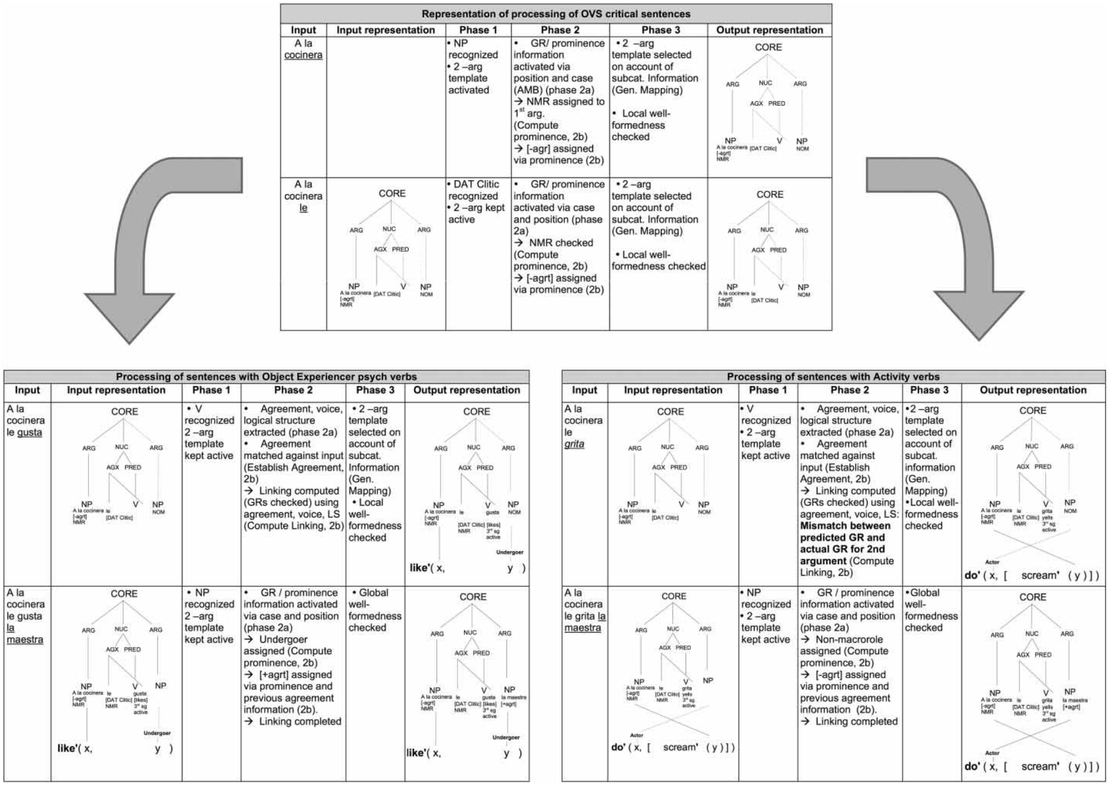

Figure 8. *Summary of the incremental processing steps involved in the comprehension of the object–verb–subject (OVS) sentences used in the current experiment adapted from Bornkessel and Schlesewsky (2006). Lower tables show the processing steps at the disambiguation region of the verb: object–experiencer psychological (psych) verbs (left) and activity verbs (right). CORE = the minimal phrase structure domain of the clause within which the nucleus and its arguments are realized; ARG = obligatory argument (noun phrase, NP, or prepositional phrase); NUC = nucleus (essentially equivalent to head, i.e., the element subcategorizing for the arguments); V = verb; AGX = agreement index (i.e., dependent of the NUCLEUS, it receives the agreement specifications of all core argument positions present in the logical structure); DAT = dative; NMR = nonmacrorole; arg = argument; agrt = agreement; gen = general; 3sg = third person singular. © 2006 by the American Psychological Association. Adapted with permission (Bornkessel and Schlesewsky, 2006).*

this leads to a marked syntax, in both unimpaired (Ferreira, 1994; Kretzschmar et al., 2012) and impaired language processing (Beretta & Campbell, 2001; Beretta et al., 2001; Piñango, 2000; Thompson & Lee, 2009).

The current study also corroborates the claim that thematic reanalysis effects can be elicited with partial prominence information provided by only one argument. This finding contrasts with results from studies on SOV languages like German. For instance, using ERPs, Bornkessel et al. (2003) elicited thematic reanalysis effects in verb-final embedded clauses containing either ObjExp psych verbs or dative-marked activity verbs. This type of clause (the so-called “middle-field clauses”) requires that both subject and object appear preverbally. In contrast to the SVO or OVS clauses used in our experiment, the parser in these studies has more information available in order to predict the verb type.

Our study only represents a first attempt to tap in the psycholinguistic consequences of the interplay between word order and verb type in Spanish. Our results use the self-paced reading time, which taps into slower processes than electrophysiological measures like EEG; therefore, we admit that a direct comparison with Bornkessel et al. (2003) cannot be made. However, we believe our work provides novel evidence in Spanish that reveals how word order may influence the predictability of the verb to come. It is open to future research whether electrophysiological and neuroanatomical correlates of the interaction between WO and verb type in Spanish are compatible with the findings from SOV languages.

In addition, our results show that reading times of the first four regions (NP/PP and V) were not affected by word order variation. This finding parallels the results of the study performed by Bornkessel et al. (2003), since these authors did not find any differences in the potentials evoked by first nominative and first dative noun phrases. They explained the absence of this effect in terms of the language-specific features of free order languages. For German, nominative and dative phrases at the beginning of the sentence can give rise to the prediction of potential "actor–undergoer" and "nonmacrorole–undergoer" prominence scales, respectively. Hence, there were no differences in parsing. This explanation extends to the differences in reading times between nominative- and dative-initial sentences in Spanish.

The effect of verb type found after the second argument is also revealing. The verbs in this experiment only differ in the way that their semantic content is syntactically realized—that is, in the way syntax-to-semantic linking is accomplished. While in activity verbs the nominative argument bears the "actor" macrorole, in ObjExp psychological verbs, the nominative argument is assigned the "undergoer" macrorole. Results of the statistical analysis showed that, as predicted by the eADM, participants took longer time to read the second argument of sentences with psychological verbs than the argument that followed activity verbs. A possible explanation for this phenomenon could be the difference in lexical frequency between activity and psychological verbs. However, lexical frequency of the verb was taken into account for the analysis of the verb and following regions and did not have any effect for reading times.

Alternatively, it may be better to analyse the verb type effect as a consequence of the computational cost of constructing the conceptual representation of events where only the "undergoer" macrorole is assigned, and not the "actor", as in sentences with ObjExp psych verbs. As shown in the lower section of Figures 7 and 8, linking the nominative argument to the undergoer macrorole requires either that the prominence scale is reconsidered (Figure 7) or that the assignment of an actor macrorole is bypassed. Prior studies have shown that ObjExp psych verbs lead to greater processing difficulty than verbs in which the nominative argument was assigned the "actor" macrorole according to several metrics, such as increased reading times, (Brennan & Pylkkänen, 2010; Cupples, 2002; Gennari & MacDonald, 2009), and decreased comprehension accuracy in patients with Alzheimer's disease (Manouilidou, de Almeida, Schwartz, & Nair, 2009) and aphasia (Beretta & Campbell, 2001; Piñango, 2006; Thompson & Lee, 2009). Results from studies that used ERPs (Bornkessel et al., 2003) and neuroimaging techniques (Bornkessel et al., 2005) also found differential brain activity after the presentation of sentences with each type of verb. The current results provide further evidence about the role of verb type, and hence linking, for sentence comprehension.

Finally, we turn to the comprehension task results. In this task, participants were asked to respond whether the question represented the event previously read on the sentence or not. These questions were designed in such a way that participants had to retrieve information about "who did what to whom" or "who feels what for whom" from the sentences. There were two main findings from these measures. First of all, the analysis of accuracy rates revealed that there was an interaction between verb type and word order in the same direction as the interaction in the online task. Questions about sentences with activity verbs were more difficult to respond to when WO was OVS than when it was SVO. Conversely, questions about sentences with psych verbs were found to be more difficult when the previously read sentence had SVO order. This could mean that readers found more difficulty in rebuilding the correct conceptual representation of the event when the semantic hierarchy of the sentence was reversed, causing longer response times. The latter outcome suggests that the presentation of verb arguments in the canonical hierarchical order could be such a robust facilitator for comprehension that the effects of presenting a noncanonical hierarchization may persist after most cognitive integrative processes are completed. This finding is also relevant for any account of word order variation, since results of the offline task confirm that word order canonicity is, among other characteristics, construction specific.

In addition, accuracy was significantly affected by word order. Participants were significantly worse at answering comprehension questions for SVO sentences than for OVS sentences. However, this effect was driven by the low accuracy in comprehension questions for SVO sentences with psych verbs. This type of sentence contains a cross-over linking between the thematic roles and the LS structure of the verb. Object-initial sentences with activity verbs also use this type of linking. However, the integrative processes for comprehension of SVO order in psych verbs require reanalysing a nominative argument into undergoer. In contrast, reanalysis of OVS sentences with activity verbs involves the assignment of the actor macrorole to a nominative constituent. The latter linking—actor/nominative—is the typical linking in Spanish, whereas the undergoer/nominative pairing is more marked. We leave for future whether using a more ecologically valid method (like eye-tracking) or a different type of comprehension task would lead to similar results.

The current results in relation to other models of sentence processing

We turn to the question of whether other models besides eADM could explain our results. We previously mentioned that the interplay between word order and verb type has been investigated in German. For instance, Bader and Bayer (2006) thoroughly describe a group of studies that involved WO alternation in order to explain how the human sentence processing mechanism (HSPM) deals with morphological case ambiguous sentences. Consider the German sentences in Example 6:

6a. Ich glaube . . .
I believe
. . . daß Maria die Lehrerin gesehen hat.
that M. the teacher seen has
that Maria has seen the teacher.
6b. # … daß Maria$_i$ die Lehrerin t$_i$ geholfen hat.
that M. the teacher helped has
that the teacher has helped Maria.

These sentences differ in that the argument structure of the verb “to see” assigns nominative–accusative case-marked arguments, while “to help” assigns a nominative–dative case-marked structure. Since proper names in German do not take case marking, and “die Lehrerin” can bear either nominative or accusative case, the parser can only disambiguate the syntactic function of each argument upon reaching the verb (and hence the intended interpretation). These authors showed that sentences like Sentence 7b produce a severe garden-path effect. In cases of morphological case ambiguity, SO word order interpretation of arguments is preferred and is later corrected if the requirements of the lexical–semantic structure of the verb call for an alternative projection of the argument structure in syntax. Nevertheless, these authors showed that garden path effects are also modulated by the type of verb encountered and seem to be more moderate when a sentence like Example 7 is read.

7. . . . . . . daß Maria die Lehrerin gefallen hat.
that M. the teacher pleased has
that the teacher has pleased Maria.

Working within the generative theoretical framework, the authors explain this phenomenon by assigning word order alternation in each sentence a different syntactic representation. On the one hand, word order in sentences like Sentence 7b is derived through “scrambling”, which is the result of an A′-movement by adjunction of an X-phrase to inflection phrase or verb phrase (Kosta, 2006). On the other hand, word order of the second group of verbs is assumed to be base generated—for example, the word order is lexically motivated, and no leftward movement within the (extended) verbal projection is present (Bader & Bayer, 2006, p. 52). As a consequence, no trace is left at the complement of the V′ position, no filler-gap dependency is established, and recovery from the garden-path effect is predicted to be easier in sentences like Sentence 8. This explanation would also account for the sentences used in the current experiment. However, it would not fully address why certain verbs take OVS as their base-generated word order, and others do not.

Another possible way to explain the data is through probabilistic models of language processing (see Chater & Manning, 2006, for an introductory review). Essentially, this perspective assumes that parsing cost depends on the probability of the co-occurrence of an input given the previous context. These models predict that there is an inverse correlation between language frequency in corpora/production and difficulty in comprehension. To our knowledge, there are no corpus studies that address the interaction between word order and verb type in Spanish. Therefore, we cannot yet draw any conclusions regarding the role of probability for word-order variation. It could be revealing to find whether the data collected from Spanish corpora are consistent with our findings given a probabilistic model.

All in all, we find that although both generative and probabilistic-based explanations are compatible with our results, they do not fully answer why one type of verb is related to one word order, and another type of verb is related to another. The generative point of view does not explain why the OS word order is base generated for this type of psych verbs and not for others. Similarly, the probabilistic account of language processing does not explain why the co-occurrence of a specific construction with a certain class of verb should take place.

By adopting the extended argument dependency model, we resort to the thematic hierarchy as an independently motivated grammatical component, which can account for the contrasting canonical orders that depend on type of verb and the easiness in processing that accompanies each of them. Prominence plays a central role in this model, which is an adaptation of the actor–undergoer (A–U) hierarchy of role and reference grammar (Van Valin, 2005). Both the OVS order for psych verbs and the SVO order for activity verbs respect the A–U hierarchy, and, hence, the divergent behaviour shown in our results is motivated. Even if it is probable that other processing models are able to motivate our data, the adoption of eADM allows us to offer an account that naturally explains the data without the stipulation of any additional machinery to that already contemplated in the model.

CONCLUSION

The current study aimed at relating the properties of a grammatical model (RRG) with those of a processing model (eADM), with the purpose of identifying the principles underlying word order patterns in Spanish.

Two different types of clause were examined: clauses with psychological verbs and those with activity verbs. Results of the current study indicate that in Spanish, comprehension and processing speed is enhanced when sentence constituent order mirrors the argument order established by the lexical semantic structure of the verb, bringing theoretical descriptions of what is considered the "unmarked" WO of the language and psychological reality of this phenomenon together. Moreover, results of the current self-paced reading task show that during ongoing comprehension, predictive mechanisms based on argument hierarchization are rapidly used to inform language processing, even when only one of the arguments has been processed. When information provided by the verb does not match the expectations built during this process, thematic reanalysis effects were found, thus replicating results from a verb-final language like German.

Supplemental material

Supplemental content is available via the "Supplemental" tab on the article's online page (http://dx.doi.org/10.1080/17470218.2014.1000345).

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