

**BEYOND AGREEMENT: HOW SYNTACTIC FEATURES
ARE ASSIGNED IN REAL TIME**

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Abstract: Feature assignment differs significantly from featural agreement as it involves aspects that are not directly manifested in the linguistic input to the speaker (like the Accusative feature of the transitive verb) but are accessible from the knowledge component only. This work is an overview of a research program that aims to explore key aspects of syntactic encoding in the structural realm of feature assignment from an experimental perspective. The project is innovative because we pit the existing models of encoding syntactic agreement against new experimental data pertaining to feature assignment effects, exploring, in particular, the role of working memory in real time computation of featural assignment. We focus on feature assignment phenomena in two Slavic languages, Bulgarian and Russian, which possess rich morphological repertoires, thus providing an excellent testing ground from an experimental perspective.

Keywords: feature assignment, Slavic, sentence processing, agreement, working memory

1. General overview

1.1. Agreement attraction errors and the existing models

Agreement attraction errors occur in spontaneous speech as well as in experimentally controlled conditions, and may include number agreement errors in subject-verb agreement (e.g. *The key to the cabinets were rusty*, cf. Bock, Miller 1991) and gender agreement errors in languages that distinguish morphological genders, such as the Slavic languages. Within the NP, respective features on the head (e.g. singular on *key*) and on the attractor (e.g. plural on *the cabinets*) come into play in computing the agreement online. More agreement errors are observed in singular-plural configurations than in plural-singular ones, as well as when the plural attractor is morphologically ambiguous between Accusative and Nominative (cf. Hartsuiker et al. 2001 for German). The first of these asymmetries is usually attributed to the markedness effect, on the assumption that the plural value is somehow more marked than the singular value. Other grammatical factors believed to affect the ratio of errors include syntactic depth of the attractor, featural similarity between the attractor and the head, grammatical as opposed to notional (conceptual) sources of the respective feature, to name a few.

Previous studies of agreement errors in English and Romance languages argued that the structural notions of c-command, hierarchy, depth and intervention are critical for understanding these performance patterns across different ranges of syntactic structures (Vigliocco, Nicol 1998; Franck et al. 2002; Franck et al. 2006, among others). In particular, significant attraction is found from a plural subject modifier in an interrogative structure even though it does not linearly intervene between the subject and the verb (e.g., *flights* in **Are the helicopter for the flights safe?*, cf. Vigliocco, Nicol 1998). Similarly, the moved object of the target verb was shown to trigger attraction in French (*patients* in **John speaks to the patients that the medicine cures*), while the object of the main verb situated in the same surface position does not (*patients* in *John tells the patients that the medicine cures*, cf. Franck et al. 2010; Franck et al. 2015). The role of structural distance is further reinforced in a cross-linguistic study of Franck et al. (2002). By increasing the complexity of the agreeing subject phrase from two to three nouns in declarative sentences (e.g. *the threat to the president(s) of the company/-ies*), these authors found that number agreement errors were more frequent after an intermediate noun (*the president(s)*) rather than after the most local noun (e.g. *company*), which is consistent with a structural rather than a linear account. These findings show that two expressions that are superficially identical but have different underlying structures show different attraction profiles.

Moreover, two expressions that are superficially different but have identical underlying hierarchical structure show similar attraction profiles. For example, the English interrogative structure generates similar attraction to the corresponding declarative (**The helicopter for the flights are safe*) despite their different surface structures (Vigliocco, Nicol 1998). These data suggest that properties of the underlying hierarchical organization of the sentence determine attraction.

How can these results be interpreted? One possibility is that the encoding system solves this problem by distinguishing the (syntactic) stage where, after the respective lexical items are retrieved, grammatical as well as structural relations among them are established. This is followed by the stage where the linear order between the (structurally fixed) lexical items is decided. The agreement relation between the subject and the copula (*is, are*) is part of the grammatical/structural encoding, and it is at this stage where external disturbance factors may influence performance and cause agreement errors (Levelt 1989; De Smedt 1990).

This is not to say that linear distance does not play a role in influencing agreement errors. In a more sophisticated series of experiments on Italian and French, Franck et al. (2006) were able to establish a gradient in computational complexity of syntactic structures inducing agreement errors and argued that structural as well as linear distance matters for the encoding of the subject-verb agreement.

Several models were proposed in the literature to account for agreement attraction effects and their modulation by the different factors mentioned above. One prominent model, termed Marking and Morphing, hypothesizes the encoding of syntactic features such as number at two different and serially organized functional levels (Eberhard et al. 2005). Marking assumes the “notional” or semantic number in the speaker’s reference model and translates it into a linguistic feature (singular or plural) pertaining to the entire subject phrase. On the other hand, Morphing is part of the structural integration process that encodes lexical items and/or morphemes into the hierarchical structural organization of the sentence. Specifically, Morphing reconciles the syntactic features selected during Marking and number specifications from the lexicon, which are argued to percolate the tree up to the subject root, where reconciliation takes place. Another assumption is that single count nouns are unspecified, or weakly specified, for number. As a result, only plural nouns have the possibility to percolate the tree and enter into the reconciliation process. If an inconsistency is encountered between number marking and morpheme specifications (e.g., in collectives, like *army*), the morpheme specifications prevail.

A different kind of model is proposed in Franck (2017) who suggested that the process responsible for selecting the agreement controller operates as a content-addressable, cue-based mechanism responsible for retrieving the subject from memory on the basis of subject retrieval cues. Franck (2017) grounded her claim in the observation that a variety of effects reported in the attraction literature in sentence production could be reinterpreted as reflecting similarity-based interference, which is considered as a signature manifestation of a cue-based retrieval mechanism. Experimental evidence indeed shows that stronger attraction arises when the attractor is more similar to the subject either semantically (Barker et al. 2001), morphologically (Lorimor et al. 2008), or syntactically. Syntactic similarity-based interference is illustrated by the report that attractors that occupy a hierarchical position of c-command with respect to the verb trigger more attraction than attractors occupying a position of simple linear precedence to the verb (Franck et al. 2006; Franck et al. 2010; Franck et al. 2015).

The third kind of model suggested recently is grounded in the self-organized approach to sentence processing (SOSP, Smith et al. 2018). Under SOSP, words instantiate treelets that attempt to combine in all possible ways in the sentence. This gives rise to competition for attachment amongst sentential elements. When one word begins to combine with another word, the features of that word will gradually pass toward the other, giving rise to a convergence of features (a mechanism known as *feature passing*). Hence, when a noun combines with a verb, the agreement features of that noun will be gradually transferred to the subject slot of the verb. If another word kicks in with the same features as the previous noun, it will be attracted to that same slot by virtue of its similarity with that noun. That is, if two words are similar in their featural specification, the competition will be stronger because they both fit the attachment requirements of the same slot. Thus, in that model similarity-based interference arises not only at retrieval, like standard cue-based retrieval models, but also at encoding, during the process of structure building.

The studies reviewed above investigate agreement attraction in language production. Furthermore, more recent research has uncovered a very similar pattern of effects in sentence comprehension grouped broadly under the rubric of *grammatical illusions*: in ungrammatical sentences in which the verb does not agree with the singular subject, readers are faster in reading the verb if the sentence contains a plural attrac-

tor that matches it (**The musicians who the reviewer praise so highly will probably win a Grammy*) than if the attractor is singular (**The musician who the reviewer praise so highly will probably win a Grammy*, cf. Wagers et al. 2009). This effect has been interpreted as to involve a cue-based process responsible for retrieval of the agreement controller when an incorrect verb is encountered; if the system finds a suitable attractor, the search process is terminated successfully. This interpretation of the grammatical illusion effect is couched in the general view that sentence comprehension is driven by a cue-based retrieval mechanism in which the parser uses syntactic and semantic cues to build the structure (e.g. McElree 2000; Lewis, Vasishth 2005). This cue-based functioning of the parser is particularly relevant when two elements that should enter into a syntactic and/or a semantic relation (e.g. a subject and its verb) are far away in the sentence. In such cases, when the parser arrives at the verb, it has to retrieve the long-distant subject to interpret the sentence. There is evidence indicating that this retrieval operation is driven by cues triggered by the verb that allow the parser to directly access the element to-be-retrieved rather than scanning the elements in the sentence one by one (e.g., McElree 2000; Van Dyke, McElree 2006). These cues can be both syntactic (e.g., number, Case) and lexico-semantic (e.g. animacy, concreteness). However, despite being highly efficient, the cue-based retrieval mechanism comes at a cost: as in sentence production, it is sensitive to similarity-based interference due to elements that also resonate with the retrieval cues (e.g. Van Dyke, McElree 2006).

1.2. Agreement attraction errors in Slavic languages

The Slavic languages, with their morphologically rich Case systems, are a priori expected to show reduced ratios of number agreement errors, presumably because of the typically non-nominative case of the attractor (cf. Rus. *klyuch ot kabinetov* ‘the key from cabinets’, lit. ‘key-NOM from offices-GEN’) which helps resolve a potential uncertainty against the attractor and toward the head of the NP, given that the latter is usually in the subject position which requires Nominative case (cf. Bock, Miller 1991). Nicol and Wilson (1999) conducted language production studies along the lines outlined above, in Russian, using both full NPs and pronouns as attractors, and found number agreement errors in this language with full NPs as attractors, though in somewhat lower proportions than in English. Lorimor et al. (2008), another experimental study on Russian, used a design crossing number (singular, plural), as well as gender (masculine, feminine) across the structural position (head, attractor). These authors found a significantly lower ratio of production errors with number agreement as compared with English, suggesting that Russian is less vulnerable to errors of this kind.

Other studies suggest a different picture with respect to gender attraction in Slavic. Badecker and Kuminiak’s proposal (2007) investigated gender attraction errors in Slovak. These authors see gender attraction errors, among other things, as a window to differentiating between different types of (morpho-) syntactic theories of markedness, potentially informing corresponding sentence production models.

An interesting pattern of results was reported in Slioussar and Malko (2016) for Russian. The authors used a comprehension task in addition to the traditional production task. Inclusion of a comprehension task allowed the authors to uncover additional preferences that the Russian speakers are guided by when processing the agreeing predicate. In particular, attraction effects were observed with feminine and neuter but not with masculine heads of the NP, suggesting that the role of the head is no less important in online computation of agreement than the role of the attractor, as traditionally assumed. Among other things, these findings again underscore the important role of the structural, syntactic factor (which determines for instance the head of the phrase as opposed to the complement or adjunct) in the online computation of agreement.

2. Feature assignment

2.1. State of the art

A prototypical case of feature or property assignment is *Case* assignment. For instance, a transitive verb assigns Accusative case to its object (e.g. *kiss her-ACC* vs. **kiss she-NOM*). In morphologically impoverished languages only a limited subset of nouns are morphologically marked for Case, e.g. in English or French only pronouns inflect according to Case they receive from their licenser. Studies on agreement

attraction errors occasionally consider feature assignment configurations, in particular with regard to Case. One study, for instance, shows that a French accusative clitic that is structurally higher, viz. c-commanding the verb (e.g. **Le professeur les lisent* “The professor read them”) creates stronger attraction in other features such as number than the dative clitic that intervenes by precedence (e.g. **Le costume leur convient* “The costume suit them”; cf. Franck et al. 2010). Another prototypical case is theta-role assignment: verbs assign theta-roles such as agent, patient or theme to their arguments depending on the semantic contribution to the argument structure and the meaning of the sentence.

Existing studies in feature or property assignment in sentence production and sentence comprehension are quite limited with respect to the repertoire of features considered, the structural domain of their distribution (mostly at the sentence level), and the range of languages investigated in these studies. Concerning the repertoire, the relevant literature concentrates mostly on theta-role assignment (to be distinguished from separate and actively researched topics concerning verbal subcategorization frames and plausibility evaluation) and Case assignment. Both properties are usually considered to be rooted in conceptual features and/or associated with grammatical function. Consequently, in the currently popular two-stage models of sentence production, both theta-role assignment and Case assignment happen at the level of grammatical encoding (e.g. Nicol 1993; Melinger et al. 2008). A point of empirical debate is whether Case assignment happens within the functional (responsible for assigning grammatical functions) or positional (responsible for structural organization) encoding, which is closely tied with the issue of choice between lexically or syntactically driven production. For instance, within Bock and Levelt’s model of sentence production, functional assignment, and therefore Case assignment, is strongly influenced by the lexical features of the sentence head (Bock, Levelt 1994). In lexically-driven production, syntactic structures are built based on the grammatical information associated with retrieved lemmas (e.g. a noun phrase is built based on the noun lemma). In contrast, in syntactically-driven production, the roles are reversed (e.g. a noun is retrieved because the syntactic slot requires it). Furthermore, Case assignment is distinguished from Case realization which presumably happens as part of the morpho-phonological encoding (Melinger et al. 2008). Another issue that often arises with respect to online Case assignment process is its interaction with the issue of incrementality: lexically-driven models of Case assignment were argued to be more compatible with strict incrementality than syntactically-based models (Kempen, Hoenkamp 1987; Levelt 1989). On the other hand, syntactically-driven models may be more sensitive to the specifics of Case distribution and in different sentence types and configurations (Dell 1986; Chang et al. 2006).

Most studies in syntactic encoding of Case concentrate on English with occasional glimpses on Germanic languages, which does not allow for appreciating the full extent of the problem concerning encoding syntactic Case. A similar situation is found when one surveys the studies in the role of Case in sentence comprehension. The literature on sentence comprehension in languages beyond English, also quite limited in coverage, distinguishes and focuses on two functions of Case relevant for the language user: helping identify the grammatical roles of the arguments which serves, among other things, the task of potentially disambiguating between the candidates for a specific grammatical role, and potentially helping in identifying clause boundaries in SOV languages (Bader, Lamers 2008). German illustrates the former aspect (cf. *Der Peter hat der Maria gefallen* “The.NOM.Peter has the.DAT.Maria pleased” vs. *Dem Peter hat die Maria gefallen* “The.DAT.Peter has the.NOM.Maria pleased”). The second aspect is illustrated by Japanese, whereby a second Nominative marked NP is unambiguously identified as an upcoming relative clause (cf. Inoue, Fodor 1995):

1. Bob-ga Mary-ni [ringo-ga atatta] inu-o ageta
 Bob-NOM Mary-DAT apple-NOM hit dog-ACC gave
 ‘Bob gave Mary the dog that the apple hit’

Research in sentence comprehension also revealed the non-trivial role of *markedness* in Case assignment. For instance, under tight processing conditions the parser seems to be unwilling to override a marked Case such as Dative by an unmarked case such as Accusative, whereas an unmarked Case is easily overridden by a marked Case in German (Bader, Bayer 2006). The parser thus behaves conservatively with respect to marked Cases, avoiding their assignment unless unambiguously indicated by the input and unwilling to retract it once it is made.

Taken together, the current state of affairs concerning Case assignment processes calls for more research that takes into account the large variety of configurations in which Case is assigned and morphologically realized in production and comprehension. The same is true for other features that can be assigned in the course of syntactic composition, and the assignment process per se as opposed to agreement. There are clear similarities between feature agreement and feature assignment in the broad sense: a) both involve information encoding at the featural level; b) both operate in specific and well-defined types of syntactic configurations; and c) both refer to properties that may at least partially be related to the conceptual level. But there are also notable differences from the perspective of the speaker's performance / language use.

One major difference can be stated in terms of working memory which provides the necessary "work space" for structural encoding of the properties of the elements that enter a relevant structural relationship. In particular, from the point of view of incremental sentence comprehension, agreement, e.g. prototypical subject-verb agreement, is a 'backward-looking' process in the sense that the agreeing element must have access to the constituent processed at an earlier point in the structure built so far. This constituent (e.g. the subject) must thus be retrieved, and its memory trace reactivated. Evidence suggests that this retrieval operation is driven by cues that allow the parser to directly access the retrieval target in a content-addressable manner (McElree 2000). The cues can be syntactic (such as number or Case) or lexical/semantic (such as animacy). Furthermore, this cue-based retrieval mechanism is subject to the so-called similarity-based interference from elements that are in some sense similar to the retrieval clues (Lewis, Vasishth 2005; Van Dyke, McElree 2006). If Franck (2017) is correct in her conjecture that agreement attraction effects reported in the literature in sentence production could be reinterpreted as reflecting similarity-based interference, which is considered as a signature manifestation of a cue-based retrieval mechanism, then we have evidence that a similar 'backward-looking' process operates in sentence production.

In contrast, feature assignment is a 'forward-looking' process, whereby one lexical item projects or predicts a feature on another lexical item 'down the path'. Aside from the host of issues that arise with respect to configurations whereby the direction of assignment is contralateral to the word order in a given language (such as object Case in OV languages), which we put aside for the moment, this raises an important question as to whether this kind of process has similar properties as agreement or other 'backward-looking' processes. Our own preliminary research on the topic suggests that the answer is yes, at least insofar as similarity-based interference may be concerned, which in turn points to an interesting conjecture that similar memory processes subserve both kinds of encoding at issue.

2.2. Case and Case-related feature assignment in Slavic

In morphologically rich languages such as Slavic, prototypical Case assigners are verbs that may assign different morphological Cases to their complements. Recent research, however, suggests that a much richer context for investigating relevant cognitive underpinnings of Case assignment and, feature assignment process more generally, is provided by Determiner phrases headed by numerals. In Bulgarian, one of the few Slavic languages that lost their overt Case morphology and is otherwise Case-impoorished similarly to English or French, one observes a Case-like morphological marker that we call the "countability" morpheme because it visibly appears only on masculine inanimate count nouns that are complements to numerals (cf. *prozortsi* "windows" vs. *pet prozoretsa* "five windows"). The countability feature appears only on nouns; any intervening adjectives must appear in the default plural form:

- | | | | |
|----|-----------------------|--------------------|---------------------------|
| 2. | <i>pet</i> | <i>darven-i/*a</i> | <i>prozorets-a/*i</i> |
| | five | wooden-PL/COUNT | window-COUNT/-PL(default) |
| | 'five wooden windows' | | |

Syntactic encoding of the count form on the nouns in Bulgarian has been found to be prone to errors very similar in nature to attraction errors discussed in the previous section. Specifically, Bulgarian speakers tend to use the incorrect feature-duplicating pattern (cf. *pet darveni prozortsi*) in the spontaneous speech. Stateva and Stepanov (2013) replicated this pattern in the experimental setting, using a cloze-like sentence completion task, whereby participants were presented, in an auto-paced reading mode, with a sentence ending with a numeral-based DP as in (3) lacking the final noun for which a lemma was provided separately.

3. Gledah kak v rekata pluvaha edinayset (krasivi)
 (gratsiozni) (beli)
 Lemma: *lebed* “swan”
 I-observed how in river swam eleven beautiful
 graceful white
 ‘I observed how eleven beautiful white swam in the river’

Participants had to supply what they considered the correct form of the noun, but they had no access to the previously read portion of the DP. The results revealed that the rate of errors is generally comparable with that found in the agreement attraction literature (<10% overall). Another finding was that the rate of errors increases with the number of intervening adjectives. This finding is consistent with the account making use of the hierarchical relations such as domination and c-command under which the error rate increases with the increase of the number of structural nodes separating the licenser (numeral) and the noun. It is also consistent with the broad class of accounts of attraction in terms of working memory as the intervening adjectives increase the distance between the numeral and the noun, therefore engaging resources of working memory to maintain the licenser. Finally, the result is compatible with the accounts in terms of similarity-based interference as intervening adjectives are a source of the increasing activation of the competing (plural) feature that intervenes in the process responsible for assigning the countability feature on the noun. Stateva and Stepanov’s (2016) follow-up corpus study of Bulgarian texts containing numeral-based DPs confirmed the adjective complexity effect pointed out above. However, a pilot sentence production study intended to mirror these results has not corroborated these findings showing no sensitivity to the structural factor in the feature assignment process (Бъркалова и др. / Barkalova et al. 2018). The inconclusive character of these findings calls for a more comprehensive inquiry into the mechanisms of feature assignment in syntactic encoding and the role of the structural factor.

Russian is a morphologically Case-rich Slavic language where feature licensers such as numerals and quantifiers (e.g. *three, some*) generally assign Genitive case to their noun complements within the DP. Furthermore, the number feature on the noun is also controlled by the licenser. In Russian, as in the majority of Slavic languages, lower numerals between two and four assign singular (e.g. *tri okna* “three window-GEN.SG”), whereas higher numerals (five and onwards) assign plural Genitive case (e.g. *pyat’ okon* “five windows-GEN.PL”) to their complement nouns. Thus, the semantic value of the numeral controls the ending on the noun via the morphosyntactic licensing mechanism. Similarly to Bulgarian, however, intervening adjectives are uniformly marked by Genitive plural (cf. *tri bol’shih okna* “three big-GEN.PL window-GEN.SG” vs. *pyat’ bol’shih okon* “five big-GEN.PL windows-GEN.PL”). Stepanov and Stateva (2018) conducted a cloze-type sentence completion experiment in Russian that has a similar design as Stateva and Stepanov’s study for Bulgarian (2013). This time, in order to fill in the inflected form of the complement noun, participants reading sentences ending in a numeral-based DP needed to keep in the working memory not only the trace of the numeral category as in Bulgarian, but also that of the actual value of the numeral, since that value controls the respective Case ending on the complement noun. On a null hypothesis, the expected pattern of potential errors would involve mismatches of the number feature of the complement noun in both directions (viz. plural with numerals not greater than 4, and singular with numerals greater than 4), in approximately equal proportion (50% chance each). What the authors found, instead, was a heavy bias toward Genitive singular (in about 4:1 ratio to Genitive plural) in participants’ assignment errors. The authors interpreted this bias as indicating that what appears to be the Genitive singular marker is actually a homophone for another morphosemantic marker, that of *countability*, similarly to the Bulgarian example above. That marker was preferred by speakers to reflect the fact that there was a numeral in the stimuli even though the actual value of the numeral could be suppressed under the memory taxing conditions.

Thus, while Bulgarian speakers seem to actively deploy the resources of working memory in order to maintain the trace of the licensing numeral as evidenced by the adjective intervention effects, in Russian the encoding of the controlled noun seems to depend more on the grammatical considerations unaffected by performance. Of course, there are grammatical differences between the two languages related to the role of grammatical Case. However, the Bulgarian and the Russian results obtained up to date illustrate the non-trivial character of speakers’ real time syntactic encoding of feature assignment within the numeral-

based DP and underscore the need to disentangle pertinent grammatical and processing effects, thus further sharpening our understanding of the extent to which the cognitive mechanisms pertaining to sentence production consult the language grammar.

3. Aims and scope of the projected research

In this section, we present an overview of our collaborative three-year research project funded by research agencies of Slovenia and Switzerland under the *Lead Agency* scheme which started in September 2020. The project aims to make important first steps into understanding the cognitive mechanisms underlying the syntactic encoding of feature assignment in sentence production and comprehension. In particular, we concentrate on the feature assignment within the Determiner phrases headed by a numeral, also involving internal modification by adjectives, adverbs and prepositional phrases such as *five old manuscripts*. This construction type offers an ideal context for studying processing effects with feature assignment because of the rich and intricate interaction between feature assigners, recipients and potentially intervening material. We test this construction type in two Slavic languages, namely, Bulgarian and Russian. Both languages have a rich morphological inventory pertaining to (numeral-based) DPs and thus provide an excellent empirical material to study processing effects pertaining to morphological phenomena. At the same time, these languages differ to a certain extent in the way numerals license (Case-related) features on their complement nouns by virtue of feature assignment. By conducting an intra-language family comparison of processing effects pertaining to the assignment of numeral-related features, we hope to construct a comprehensive model of feature assignment within the DP and compare it with existing models of sentential agreement in terms of processing factors that enter into consideration in each phenomenon. We also intend to provide a strong cross-linguistic dimension to our study.

We take the current state of knowledge into agreement attraction errors in sentence production and grammatical illusions in sentence comprehension as the starting point for our investigation, asking to what extent the online feature assignment process mirrors that in sentential agreement, and what the main differences are. In particular, the following four research questions are being addressed:

1. Is feature assignment sensitive to the structural factor both in agreement production and comprehension? What are the relative roles of structural and linear distance in licensing a particular feature within the DP, such as the countability feature?
2. Is feature assignment subject to similar memory mechanisms as sentential agreement? Is there a relative memory “cost” of the feature assignment process? To what extent is similarity-based interference relevant? How stable is the feature assignment process under the memory taxing conditions?
3. How does the rich surface morphology in languages like Slavic facilitate the retrieval of the feature being assigned, as opposed to languages with poorer morphology?
4. What is the role of the feature licenser (controller) in the assignment process? What lexical and/or semantic properti(es) of the latter, if any, are activated in selecting the feature assigned on the target?

4. Methods

The project involves a series of 7 experiments, each containing two language-specific versions in Bulgarian and Russian, for a total of 14 experimental manipulations. The research questions above are tackled by testing hypotheses pertaining to the following aspects of feature assignment: the role of structural depth and linear distance in intervening modification, directionality of errors, magnitude of the numeral interference effect, grammatical illusions with plural or numeral intervention. Two methodologies are used. One is the sentence-completion task using the *forced-choice response time paradigm*. Sentences ending in a numeral based DP (usually as a postverbal subject or object of the sentence) are presented word by word following the Rapid Serial Visual Presentation technique (Staub 2009; Staub 2010). Participants select the final noun form that they believe correctly completes the sentence within a limited time period. This task has been shown to be an efficient alternative in replicating attraction results in agreement contexts obtained with the standard sentence completion technique used in earlier works (cf. Staub 2010; Villata et al.

2018). The other methodology is *self-paced reading*: sentences appear word by word (or region by region) on a computer screen, and the participants read them consecutively by pressing the space bar. The time between any two presses is assumed to reflect the reading time of the respective region. The reading task is followed by comprehension questions. Recent findings in the agreement attraction literature suggest that errors made by speakers in comprehension questions are often an efficient indicator of attraction effects, along with reading times (Villata et al. 2018). We, therefore, use accuracy in comprehension questions as an additional dependent measure on a par with RTs.

The materials for all experiments involve a series of sentences ending in a numeral-based DP. In these DPs, the numeral always assigns a (countability-like) feature to its complement noun that, depending on the language, either has its own morphological manifestation in certain declension paradigms, as in Bulgarian, or is homophonous with a particular Case form (e.g. Genitive) as in Russian. If the numeral-based DP contains also modifying adjectives, adverbs or prepositional phrases, the assigned feature does not ‘spread’ to those. In such cases, adjectives, in particular, always appear in regular plural. The morphological discrepancy between the countability marker on the noun and on the modifying adjectives creates processing tension that was shown in our previous work to lead to production errors. We explore this phenomenon in detail and develop a processing model that predicts the relevant empirical effects in production as well as in comprehension. The research group is currently at the stage of data collection for the first series of experiments, each of which involves 80 healthy participants, matched by age, education and socio-economic status.

5. Significance of the project results

The project opens a new venue of investigation in sentence processing research by looking into feature assignment phenomena in Bulgarian and Russian. A parallel investigation adds to the empirical depth of our analysis, providing an opportunity to identify common processing routines as well as potentially differing patterns pertaining to microvariation in the morphological systems of the two languages, that could not be achieved when looking at languages with poorer morphology such as English.

Understanding the cognitive mechanisms for manipulating syntactic features also has important practical consequences. One concerns development of therapeutic tools for language-related disorders. Agreement mechanisms have been shown to be affected in pathological circumstances such as Specific Language Impairment in children (Franck et al. 2004), and it is very likely that feature assignment will follow suit when scrutinized against the data from populations affected with language difficulties, as both domains belong to a natural class of syntactic feature binding, also involving similar mental resources such as working memory.

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References

- Badecker, Kuminiak 2007: Badecker, W., F. Kuminiak. Morphology, Agreement and Working Memory Retrieval in Sentence Production: Evidence from Gender and Case in Slovak. – In: *Journal of Memory and Language*, vol. 56, pp. 65 – 85.
- Bader, Bayer 2006: Bader, M., J. Bayer. *Case and Linking in Language Comprehension: Evidence from German*. Berlin: Springer.
- Bader, Lamers 2008: Bader, M., M. Lamers. Case in Language Comprehension. – In: Malchukov, A., A. Spenser (Eds.) *The Oxford Handbook of Case*. Oxford: Oxford University Press, pp. 402 – 418.
- Бъркалова и др. 2018: Бъркалова, П., П. Статева, А. Степанов. Теоретични и психолингвистични аспекти на бройната форма в българския език. – В: *Български език*, № 65 (4), с. 38 – 57. (Barkalova et al. 2018: Barkalova, P., P., Stateva, A. Stepanov. Theoretical and Psycholinguistic Aspects of the Count Form in Bulgarian. – In: *Balgarski ezik*, vol. 65 (4), pp. 38 – 57.)
- Barker et al. 2001: Barker, J., J. Nicol, J., M. Garrett. Semantic Factors in the Production of Number Agreement. – In: *Journal of Psycholinguistic Research*, vol. 30, pp. 91 – 114.

- Bock, Levelt 1994: Bock, K., W. J. M. Levelt. Language Production: Grammatical Encoding. – In: Gernsbacher, M. (Ed.) *Handbook of Psycholinguistics*. San Diego: Academic Press, pp. 945 – 984.
- Bock, Miller 1991: Bock, K., C. A. Miller. Broken Agreement. – In: *Cognitive psychology*, vol 23 (1), pp. 45 – 93.
- Chang et al. 2006: Chang, F., G. S. Dell, K. Bock. Becoming Syntactic. – In: *Psychological Review*, vol. 113 (2), pp. 234 – 272.
- De Smedt 1990: De Smedt, K. *Incremental Sentence Generation: a Computer Model of Grammatical Encoding*. Doctoral dissertation, NICI Technical Report 90-01, University of Nijmegen.
- Dell 1986: Dell, G. S. A Spreading-activation Theory of Retrieval in Sentence Production. – In: *Psychological Review*, vol. 93 (3), pp. 283 – 321.
- Eberhard et al. 2005: Eberhard, K. M., J. C. Cutting, K. Bock. Making Sense of Syntax: Number Agreement in Sentence Production. – In: *Psychological Review*, vol. 112, pp. 531 – 559.
- Franck 2017: Franck, J. Syntactic Encoding: Novel Insights into the Relationship between Grammar and Processing. – In: Fernández, E., H. Cairns (Eds.) *Blackwell Handbooks in Linguistics: The Handbook of Psycholinguistics*. New Jersey: John Wiley & Sons. pp.13 – 37.
- Franck et al. 2002: Franck, J., G. Vigliocco, J. Nicol. Attraction in Sentence Production: The Role of Syntactic Structure. – In: *Language and Cognitive Processes*, vol. 17 (4), pp. 371 – 404.
- Franck et al. 2004: Franck, J., S., Ohayon, L. Chillier-Zesiger, U. H. Frauenfelder, C. Hamann, L. Rizzi, P. E. Zesiger. Normal and Pathological Development of Subject-verb Agreement in Speech Production: A Study of French Children. – In: *Journal of Neurolinguistics*, vol. 17 (2–3), pp. 147 – 180.
- Franck et al. 2006: Franck, J., G. Lassi, U. H. Frauenfelder, L. Rizzi. Agreement and Movement: A Syntactic Analysis of Attraction. – In: *Cognition*, vol. 101, pp. 173 – 216.
- Franck et al. 2010: Franck, J., G. Soare, U. H. Frauenfelder, L. Rizzi. Object Interference in Subject-verb Agreement: The Role of Intermediate Traces of Movement. – In: *Journal of Memory and Language*, vol. 62 (2), pp. 166 – 182.
- Franck et al. 2015: Franck, J., S. Colonna, L. Rizzi. Task-dependency and Structure-Dependency in Number Interference Effects in Sentence Comprehension. – In: *Frontiers in Psychology*, vol 6 (349), pp. 1 – 15.
- Hartsuiker et al. 2001: Hartsuiker, R. J., I. Antón-Méndez, M. van Zee. Object Attraction in Subject-verb Agreement Construction. – In: *Journal of Memory and Language*, vol. 45 (4), pp. 546 – 572.
- Inoue, Fodor 1995: Inoue, A., J. D. Fodor. Information-paced Parsing of Japanese. – In: Mazuka, R., N. Nagai (Eds.) *Japanese Sentence Processing*. Hillsdale, NJ: Lawrence Erlbaum Ass. pp. 9 – 63.
- Kempen, Hoenkamp 1987: Kempen, G., E. Hoenkamp. An Incremental Procedural Grammar for Sentence Formulation. – In: *Cognitive Science*, vol. 11 (2), pp. 201 – 258.
- Levelt 1989: Levelt, W. J. M. *Speaking: From Intention to Articulation*. Cambridge, Massachusetts: MIT Press.
- Lewis, Vasishth 2005: Lewis, R. L., S. Vasishth. An Activation-based Model of Sentence Processing as Skilled Memory Retrieval. – In: *Cognitive Science*, vol. 29 (3), pp. 375 – 419.
- Lorimor et al. 2008: Lorimor, H., K. Bock, E. Zalkind, A. Sheyman, R. Beard. Agreement and Attraction in Russian. – In: *Language and Cognitive Processes*, vol. 23 (6), pp. 769 – 799.
- McElree 2000: McElree, B. Sentence Comprehension is Mediated by Content-addressable Memory Structures. – In: *Journal of Psycholinguistic Research*, vol. 29, pp. 111 – 123.
- Melinger et al. 2008: Melinger, A., T. Pechmann, L. Pappert, L. Case in Language Production. – In: Malchukov, A., A. Spencer (Eds.) *The Oxford Handbook of Case*. Oxford: OUP, pp. 384 – 401.
- Nicol 1993: Nicol, J. Reconsidering Reactivation. – In: Altmann, G., R. Shillcock (Eds.) *Cognitive Models of Speech Processing*. Hillsdale, NJ: Lawrence Erlbaum Ass., pp. 321 – 347.
- Nicol, Wilson 1999: Nicol, J., R. Wilson. Agreement and Case-marking in Russian: A Psycholinguistic Investigation of Agreement Errors in Production. – In: *Proceedings from FASL*. Ann Arbor, MI: Michigan Slavic Publications, pp. 314 – 327.
- Slioussar, Malko 2016: Slioussar, N., A. Malko. Gender Agreement Attraction in Russian: Production and Comprehension Evidence. – In: *Frontiers in Psychology*, vol. 7.
- Smith et al. 2018: Smith, G., J. Franck, W. Tabor. A Self-organizing Approach to Subject-verb Number Agreement. – In: *Cognitive Science*, vol. 42 (4), pp. 1043 – 1074.
- Staub 2009: Staub, A. On the Interpretation of the Number Attraction Effect: Response Time Evidence. – In: *Journal of Memory and Language*, vol. 60 (2), pp. 308 – 327.
- Staub 2010: Staub, A. Response Time Distributional Evidence for Distinct Varieties of Number Attraction. – In: *Cognition*, vol. 114 (3), pp. 447 – 454.
- Stateva, Stepanov 2013: Stateva, P., A. Stepanov. Agreement Errors in Numerical Phrases: Structural Distance and Competing Licensors. – In: *International Conference on Architectures and Mechanisms for Language Processing-AMLAP 2013*, Marseille, France.

- Stateva, Stepanov 2016: Stateva, P., A. Stepanov. Agreement Errors and Structural Distance: A Corpus Study of Bulgarian. – In: *Zeitschrift für Slawistik*, vol. 61 (3), pp. 448 – 462.
- Stepanov, Stateva 2018: Stepanov, A., P. Stateva. Countability, Agreement and the Loss of the Dual in Russian. – In: *Journal of linguistics*, vol. 54 (4), pp. 779 – 821.
- Van Dyke, McElree 2006: Van Dyke, J. A., B. McElree. Retrieval Interference in Sentence Comprehension. – In: *Journal of Memory and Language*, vol. 55, pp. 157 – 166.
- Vigliocco, Nicol 1998: Vigliocco, G., J. Nicol. Separating Hierarchical Relations and Word Order in Language Production: Is Proximity Concord Syntactic or Linear? – In: *Cognition*, vol. 68 (1), pp. B3 – B29.
- Villata et al. 2018: Villata, S., W. Tabor, J. Franck. Encoding and Retrieval Interference in Sentence Comprehension: Evidence from Agreement. – In: *Frontiers in Psychology*, vol. 9 (2), pp. 1 – 16.
- Wagers et al. 2009: Wagers, M., E. Lau, C. Phillips. Agreement Attraction in Comprehension: Representations and Processes. – In: *Journal of Memory and Language*, vol. 61(2), pp. 206 – 237.

ОТВЪД СЪГЛАСУВАНЕТО: ПРИПИСВАНЕ НА СИНТАКТИЧНИ СВОЙСТВА В РЕАЛНО ВРЕМЕ

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Резюме: Приписването на (граматическо) свойство (например акузатив на транзитивния глагол) се отличава значително от съгласуването поради факта, че използва аспекти, които не се проявяват в езиковата информация, давана от говорещия. Приписването на свойство по-скоро използва като ресурс единствено езиковата компетентност на говорещите. Тази статия представлява обзор на една обширна изследователска програма, която си поставя за цел изучаването на основните аспекти на синтактичния запис на приписването на свойства на структурно равнище от експериментална гледна точка. Проектът е иновативен, тъй като противопоставя съществуващите модели за запис на синтактичното съгласуване с нови експериментално получени данни и по-специално изследва ролята на работната памет при обработката на приписването на свойства в реално време. Във фокуса на изследването попадат явления от български и руски, които заради богатия си морфологичен ресурс предоставят отлична възможност за експериментални изследвания.

Ключови думи: *приписване на граматическо свойство, славянски езици, обработка на изречението, съгласуване, работна памет*

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