The effects of verb's inflectional entropy on the processing of reflexive objects

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Abstract

Consider the minimal pair:

a. *Maria prijst/ helpt zichzelf*
   Maria praises/ helps herself
b. *Maria prijst/ helpt Kathrin*
   Maria praises/ helps Kathrin

Interpretation of zichzelf requires an intra-sentential referent while Kathrin does not. We use an information-theoretical measure to quantify processing complexity, namely the inflectional entropy of the verbal paradigm, a measure that reflects how an inflectional paradigm is organized in long term memory (LTM). We show that interpretation of a referentially dependent lexical item like zichzelf requires an operation on the verb itself because its speed of processing is modulated by the complexity of the verb as quantified by the inflectional entropy of its paradigm. More precisely, the value of the inflectional entropy influences the speed of activation of an inflected verb type from LTM as well as its re-accessing in working memory (WM). Furthermore, we argue that the speed is modulated according to the principle "what is easier to activate is harder to re-access".

In our experimental study, we used the self-paced reading task, measuring reading times at the point of the verb and at that of the object. We attested that verbs belonging to high entropy paradigms are retrieved faster than those belonging to low entropy paradigms. Crucially, when the verb is re-accessed, as in the cases of referentially dependent objects like zichzelf, verbs with high inflectional entropy delay the interpretation of the object, as reflected by the longer reading times. In other words, zichzelf is processed faster when it is the object of a praise-type verb (low inflectional entropy) than when it is the object of a help-type verb (high inflectional entropy).

Keywords: verbal entropy, processing, reflexives, dependency, re-accessing

1. Introduction

"He who despises himself nevertheless esteems himself thereby, as a despiser". In this quote by Friedrich Nietzsche, appearing in Part 4 of "Beyond Good And Evil" (1909), one needs to think about two things regarding the word *himself*. First of all, replacing *himself* with *herself* will be infelicitous for both parts of the proposition. Similarly, replacing *he* with *she* will cause problems in comprehension because *himself* is not fully determined on its own but is "dependent" of other expressions. Interpretation of *himself* requires a male entity, *within* the sentence, to which it can refer to. No matter what theory of language one follows, it is shown in various studies that resolving referential dependencies for reflexives like *himself* is a very fast process; e.g. faster than for pronouns (e.g. *him*) or proper names (e.g. *Mark*) or noun phrases (e.g. *the doctor*) (Koornneef, 2008 and references therein). An interesting question is whether differences in verbs influence interpretation of *himself*. Could there be a difference in speed with which the referent of *himself* is resolved in the first part of the quote (in which it is an object of the verb 'to despise') compared to the second part of the quote (in which it is an object of the verb 'to esteem')? The purpose of this study is exactly this; to investigate if the processing of *himself* depends on the complexity of the verb, as measured by information-theoretical means. We use adapted measures of Information Theory as proposed by Shannon (1948), and more precisely the inflectional entropy of the verb, to quantify each verb's complexity. We show that the speed of processing of *himself* is modulated by the complexity of the verb with which it forms a predicate.

This article is organized as follows: First, some notions of Information Theory are introduced in section 2, and section 3 explains the relevance of inflectional entropy to language processing. Section 4 describes the experiment we conducted, and, in section 5, we discuss our results and further thoughts.

2 Information Theory and inflectional entropy

This study shows how entropy (H) of the inflectional paradigm of a verb influences the speed of object integration and interpretation. To enable the reader to understand what that means, we need first to explain the logic behind the notions of Information Theory, and we will do so, in a rather "mathematically-informal" way, though retaining the necessary preciseness.

Shannon introduced the notion of *Information Load* (IL) and *Entropy* (H) of a discrete random variable X to express the uncertainty associated with this variable and its distribution (Shannon, 1948). For reasons of simplicity, we will shift from a discrete random variable to a discrete set consisting of c items. This set can be seen as a collection of any type of discrete elements with shared characteristics; e.g. a collection of books, of integers, of dresses in a cupboard or of words, inflected verb forms, etc. We will refer to the actions that can be applied to this set as a "message" (in information-theoretical terms), which can be understood as e.g., "a choice of a book", "let the second integer be even", the realization of which is estimated by their probability p. This "shift" from a discrete *variable* to discrete *items of a* set gives rise to Formulas (1, 2), as adapted by Baayen, Feldman, & Schreuder (2006).

1. Information load carried by an item i, measured in bits:

$I_i = -log_2 p_i$, where p_i denotes the probability of i, related to an event m

2. Entropy of a c-item set f, measured in bits:

$$H_{f_c} = -\sum_{m=1}^{c}(p_m * log_2 p_m)$$

To clarify how the formulas work, let us take a set to be *f* = "collection of *c* books" and an event m = "choose one book out of the set *f*". If the collection consists of only one book (*c*=1), then the probability to choose the only book *b* will be $p_b = 1$. Since there is no uncertainty about the choice of a book in a singleton set, the entropy will, unsurprisingly, be $H_{f_1} = -(1 * \log_2 1) = 0$ bits and the information carried by the choice of the book will be $I_b = -\log_2 1 = 0$ bits.

In the case that *c=8* and the books are identical, they will have the same probability of being chosen $p_b = \frac{1}{c} = \frac{1}{8}$. Consequently, *f* = "collection of 8 identical books", and the information carried by each "book-choice" is $I_b = -\log_2 \frac{1}{8} = 3 \text{ bits} \equiv H_{f_8} = -\left(8 * \frac{1}{8} * \log_2 \frac{1}{8}\right)$. [1]

However, a set with items that all have the same probabilities need not always be the case. In fact, most of the times, this situation does not occur in real world. Let us take again a set of 8 books that have *different* probabilities of being chosen (because, for example, some are more prominent/big/interesting than others), and let $p_1 = p_2 = p_3 = p_4 = \frac{1}{8}$, $p_5 = p_6 = \frac{1}{16}$ and $p_7 = p_8 = \frac{3}{16}$. It follows that the individual information that each book carries is: $I_1 = I_2 = I_3 = I_4 = -\log_2 \frac{1}{8} = 3$ bits, $I_5 = I_6 = -\log_2 \frac{1}{16} = 4$ bits and $I_7 = I_8 = -\log_2 \frac{3}{16} = 2.415$ bits. One can notice that the lower the probability of an item gets, the higher is the information that this item carries. Entropy of that set of books will be: $H_{f_8} = -\sum_{m=1}^{8} p_i * log_2 p_i = -\sum_1^4 \frac{1}{8} * log_2 \frac{1}{8} - \sum_5^6 \frac{1}{16} * log_2 \frac{1}{16} - \sum_7^8 \frac{3}{16} * log_2 \frac{3}{16} = 4 * \frac{1}{8} * 3 + 2 * \frac{1}{16} * 4 + 2 * \frac{3}{16} * 2.415 = 2.906$. Thus, entropy changes when the probabilities, *within* the set, vary and it is a measure of the *uncertainty* to predict the outcome of a message.

There exists, in general, some confusion regarding the notion of information. The technical notion of information, as a measure of uncertainty, is often confused with the intuitive notion of information that implies something clear and *informative*. The technical notion of information, as stressed even by Shannon himself, is a measure of how *unclear* something is and, in this sense, it is not surprising that buying a winning lottery ticket is a more informative event (as there is less certainly which one is the winning one) than flipping a coin and getting a tail (50% chance). Formulas 1 and 2 measure the value of the technical notion.

With respect to lexical access, we use the adapted to language formulas 3 and 4, following Kostić's original claim (Kostić, et al., 2003), supported experimentally (Moscoso del Prado, et al., 2004; Milin, et al., 2009), that the uncertainty of the morpho-syntactic specification of a certain lexical form (expressed in the formula as *R* - the number of potential functions/ meanings) increases its information load. IL as estimated by formula 3, hence estimates the cost of the type's activation in bits. If a certain verb form w_1 (a particular morphological composition, an inflected type) can be both an infinitive, a 1st person plural, a 2nd person plural, and a 3rd person plural, then this form will have a higher uncertainty (thus a higher information load), resulting in a "heavier", and costlier type than a form w_2 that can only be an infinitive and a 1st person singular (provided of course that these two forms have equal frequencies). Numerically, if w_1 and w_2 have a probability $p_1 = p_2 = 0.4$, $R(w_1) = 4 > R(w_1) = 2$ and $IL(w_1) = 3.322 > IL(w_2)=2.322$, making w_2 harder to activate. More functions create more ambiguity regarding the suitable environment a verb type can be used in, corresponding to higher load and cost correlated to the individual form's initial activation.

The cost of activation of the whole network is expressed by the inflectional entropy (4). To move from mathematics to language, we can think of sets being classes (e.g. nouns, prepositions, verbs) or, on a smaller scale, subclasses, like, in our case, the inflectional paradigm of the verb, which is the set of its inflected variants. Inflectional entropy depends on the number of inflected forms and on the information load each form carries. It can be visualized as the degree of uniformity of a paradigm distribution (Figure 1).

Information load and inflectional entropy are language-dependent measures and, because the present study investigates the effects of inflectional entropy in Dutch, we will exemplify the calculations of IL and H (Table 1) for the verb *helpen* (to help), in Dutch.

Table 1: Inflectional Paradigm of "helpen", (to help, in Dutch)

PRESENT	1st, 2nd sg	ik, jij (interrogative)	**Help**
	2nd; 3rd sg	jij, hij/ zij/ het/ u	**Helpt**
	1st, 2nd, 3rd pl	wij, jullie, zij	**Helpen**
PAST	1st, 2nd, 3rd sg	ik, jij, hij/ zij/ het/ u	**Hielp**
	1st, 2nd, 3rd pl	wij/jullie/zij hebben	**hielpen**
PAST PERFECT	1st sg	ik heb	**geholpen**
	2nd sg	jij hebt	
	3rd sg	hij/zij/het/u heeft	
	1st, 2nd, 3rd pl	wij, jullie, zij hebben	
FUTURE	1st, 2nd, 3rd sg	ik, jij, hij/ zij/ het/ u zal	Helpen
	1st, 2nd, 3rd pl	wij, jullie, zij zullen	
FUTURE PERFECT	1st, 2nd, 3rd sg	ik, jij, hij/ zij/ het/ u zal hebben	geholpen
	1st, 2nd, 3rd pl	wij, jullie, zij zullen hebben	
INFINITIVE			Helpen
PARTICIPLE			geholpen

For each verb type *i*, the containing information (*IL*) is calculated as a function of the type's relative frequency (*F*) *and* the linguistic functions (*R*) the type can serve.

3. Information Load of verb form *i*:

$$IL_i = -log_2 \frac{\frac{F_i}{R_i}}{\sum_1^c \frac{F_m}{R_m}}$$

The information encapsulated in the verb's inflectional paradigm is derived as in 4,

4. Inflectional entropy of an inflectional paradigm f:

$$H_f = -\sum_{i=1}^{c} \frac{\frac{F_i}{R_i}}{\sum_1^c \frac{F_m}{R_m}} * log_2 \frac{\frac{F_i}{R_i}}{\sum_1^c \frac{F_m}{R_m}}$$

We calculate IL and H for *helpen* as follows (Table 2): Six forms (c= 6) are identified from Table 1 above; *help, helpt, hielp, hielpen, geholpen* and *helpen*. We obtained relative frequencies from the CELEX lexical database (Baayen, et al., 1995). For each verb type we identified the number of syntactic functions (R) the verb type serves in its paradigm, and we calculated the ratios of relative frequencies to functions (F/R). To get a distribution of the probabilities of the paradigm we normalized the ratio, which resulted in a probability value p for each verb form.

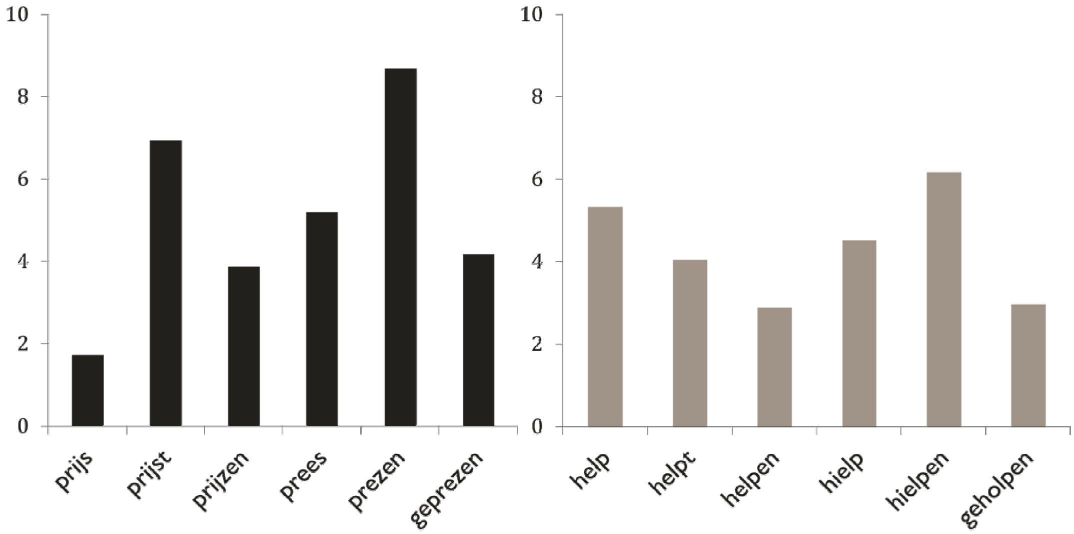
Table 2: Example of calculation of information load for the case of "helpen"

c = 6	help	helpt	helpen	hielp	hielpen	geholpen
F	583	1420	6336	1533	302	1496
R	2	2	4	3	3	1
$\frac{F_i}{R_i}$	291.5	710	1584	511	100.67	1496
$p_i = \frac{\frac{F_i}{R_i}}{\sum_{i=1}^{6} \frac{F_i}{R_i}}$	.0621	.151	.338	.109	.021	.319
$I_i = -\log_2 p_i$	4.009	2.725	1.567	3.199	5.543	1.645
H = entropy of the family = - Σ [p_i* $\log_2(p_i)$] = 2,1799						

Note: $\sum_{i=1}^{6} \frac{F_i}{R_i} = 4693,2$

Low inflectional entropy indicates that the memory traces of the inflected verb types (IL) are distributed in a more "distinct" way within the paradigm, namely, some types (of the paradigm) carry more information than others (e.g. *prijzen* left panel). *High* entropy (e.g. *helpen*, right panel) describes more "uniform" distributions; memory traces of all types are more similar to each other and carry more or less the same information.

Figure 1: Distribution of paradigms with low inflectional entropy (prijzen) and high inflectional entropy (helpen). Bars represent the information load of each verb type of the paradigm.



Individual information load is an index of the strength of memory traces and of the cost of activation of each inflected *verb type* in LTM. Inflectional entropy is an index of how the inflected items are organized as a *whole inflectional paradigm* in LTM. But, what is the psychological reality of inflectional entropy and how can the distinction between low and high inflectional entropy be relevant for language processing?

3. Inflectional entropy as a measure of verb complexity

In the previous section we demonstrated how inflectional entropy is calculated from the frequency and linguistic properties of the inflected verb types, but how is this tool relevant to language processing?

Inflectional entropy reflects the way the items' paradigms are organized in long-term memory (LTM) and can be seen as a measure of the paradigms' complexity. In principle, it quantifies the processing cost of activation of lexical types, but, as this study shows, also influences the processing cost of object's integration into a structure.

Before going into detail on language processing, let us first see how language comprehension proceeds. We distinguish, at least[2], three levels for the comprehension of a proposition:

- level 1: Activation of lexical items with various memory traces in LTM that become available to working memory (WM)
- level 2: Combination of lexical items into a structure and computation of semantic interpretation
- level 3: Application of discourse and world knowledge for the interpretation of the proposition

To exemplify this, consider 5 and 6:

5. Maria helpt zichzelf
 'Maria helps herself'
6. Maria helpt Kathrin
 'Maria helps Kathrin'

In both cases 5 and 6, *Maria, helpt* and *zichzelf* (or *Kathrin*, respectively), are activated in LTM and become available to WM for further combination into language structure (level 1). In level 2, the items must integrate into a structure and a distinction between the two sentences emerges. In 5, *zichzelf* needs to find an intra-sentential source for a referent. More specifically, it must re-access the verb in order to access its subject, contrary to 6, where *Kathrin* does introduce a new entity, but does *not* require supplementary computation involving the verb, apart from predicate completion (as an object of the verb). Interpretation of 6 is completed in level 3, where *Kathrin* finds its referent in the discourse. Interpretation of 5 is completed in level 2.

Focusing on level 1, activation of lexical items in LTM makes them available to WM and the "strength" of their availability is determined by the "ease" of their activation and quantified by the inflectional entropy of their paradigm. In fact, information theoretical measures have been shown to correlate with response latencies in language processing experiments, and, most importantly, they are *better* predictors of response latencies than simple surface frequencies. Kostić studied the effect of the distributions of exponents in noun retrieval in Serbian and found that inflected nouns with an ending that carried a lower information load were easier to retrieve (faster response latencies) than those carrying more information (1991; 1995). Inflectional entropy, on the other hand, seems to have a reverse effect. In various lexical decision tasks, nouns belonging to a paradigm with higher inflectional entropy were activated faster than those belonging to a paradigm with lower inflectional entropy (Baayen, et al., 2006; Milin, et al., 2009; Milin, et al., 2009).

Additionally, and closer to the present study, since we are interested in inflected verbs, van Ewijk & Avrutin (2011) tested young and elderly subjects in a lexical decision task using Dutch verbs belonging to families of varying inflectional entropies and also found that inflected verbs of high entropy paradigms were recognized faster than those of low entropy paradigms. These results should not come as a surprise. When an item is activated, activation automatically spreads to its paradigm and energy is needed to support this spreading. The amount of this energy depends, in information-theoretical terms, on how different the indices of the cost of activation of each inflected type is, as computed by *IL* and visualized by the "height" of the lines (recall Figure 1 for *helpen*). In the case of high entropy paradigms, the indices of the cost of activation of each inflected verb type are "close" to each other. Thus, the energy that is "lost" while activating the related forms of the paradigm is less in high inflectional entropy paradigms, than in low inflectional ones. In the latter, where the "distance" among the cost of activation is larger (recall for *prijzen*), more energy is required to support the spreading.

In a nutshell, a "homogeneous" distribution, corresponding to a *high* inflectional entropy, facilitates (in comprehension) the activation of inflected verb types belonging to it, reflected on the *faster* response times. Crucially, all studies above investigated the effects of inflectional entropy on lexical retrieval in *isolation*, and not in (whole) *sentence* processing.

The issue addressed in this paper is how inflectional entropy of the verb influences integration of the object and whether this influence is different in cases with and without an intra-sentential dependency (7).

7a.	Maria prijst/ helpt zichzelf Maria praises/ helps herself	intra-sentential referential dependency (+d)
b.	Maria prijst/ helpt Kathrin Maria praises/ helps Kathrin	no referential dependency (-d)

In other words, our research questions can be summarized as:

Q1: Will zichself/ Kathrin be integrated faster in the case of a verb like *prijzen* than in that of
a verb like *helpen*?

Q2: Is there a difference in the way verbal inflectional entropy modulates object integration,
depending on whether the object is a reflexive (+d;) or a nominal phrase (-d;)?

The next section presents the experimental study we conducted where it is shown that indeed the speed of processing of referentially-dependent elements such as *zichzelf* is modulated by the inflectional entropy of the verb, which is not the case for the processing of nominal phrases such as *Kathrin*.

4. Experiment

The goal of the experiment is to investigate whether the inflectional entropy of the verb influences object integration, and whether this influence is the same for referentially-dependent objects compared to non-referentially-dependent ones.

4.1 Participants & Procedure

45 students of Utrecht University, 10 of them male, aged 21;0-29;1 (years; months, MA: 22;5) were paid to participate in the experiment. All are native speakers of Dutch and were naive as to the purpose of the study.

The moving-window self-paced reading paradigm was used (Just, et al., 1982), in which a sentence is first displayed as a series of dashes on the screen, each one representing a word in the text. The participants are asked to press a button that replaces the dash with a word. Subsequent button presses replaced the previous words by dashes while the current word is shown. Only one word is visible at any given time. The participants are instructed to read as fast as possible, making sure that they comprehend the sentence. This method allows readers to control the speed with which they read a text. The latencies of the button are shown to correlate with the time course of the cognitive processes during reading and text comprehension and they will serve as our measure unit. The experiment was presented using the ZEP experimental software (Veenker, 2011). Participants completed the task in a soundproof booth in 25-minute sessions.

4.2 Materials and Design

24 Dutch transitive verbs were chosen, independently, according to their inflectional entropy (H_i), which was calculated as described in section 0. Entropies varied from 1.043 to 2.323 bits; mean 1.863 bits. They were further classified in two independent ($p<.001$) low/high inflectional entropy groups.

Each verb was used in 2 conditions; with a referentially-dependent object (+d; reflexive) and with a non-referentially-dependent object (-d; proper name), resulting in 48 experimental items (Table 3).

Table 3: Experimental Design

Entropy level (H)	Low e.g. *danken* (to thank)	high e.g. *helpen* (to help)	*total*
#of items	12 x 2 conditions = 24	12 x 2 conditions = 24	48

The intervening words between the verb and the object were kept identical in the regions of interest, ensuring that the carried information and hence, the processing cost, will be constant across items. Although the critical regions are the point after the verb (rg 2), and the point of object integration (rg 7), we included a following region (rg 8 - 11) to account for spillover effects (Table 4).

Varying the inflectional entropy (H) of the intervening verb we succeeded in identifying how an information-theoretical measure can influence object integration and whether this influence is the same in referentially-dependent versus referentially independent object types.

Table 4: Structure of experimental items

Condition	*He(She)* Verb*, in the most cases,* him(her)self/ Loes *and not the other players*					
+d; reflexive -d;proper name	HIJ(ZIJ)	*verb*	in de meeste gevallen	ZICHZELF Loes	en niet de andere	spelers
	varying entropy		constant IL	Object	spill over	
Region	1	2	3 4 5 6	7	8 9 10 11	12

All experimental items were reviewed by 5 independent native speakers of Dutch. Only the items ranked with a 4 or 5 degree of plausibility (on a scale of 0-5/unacceptable-plausible) were included in the experiment.

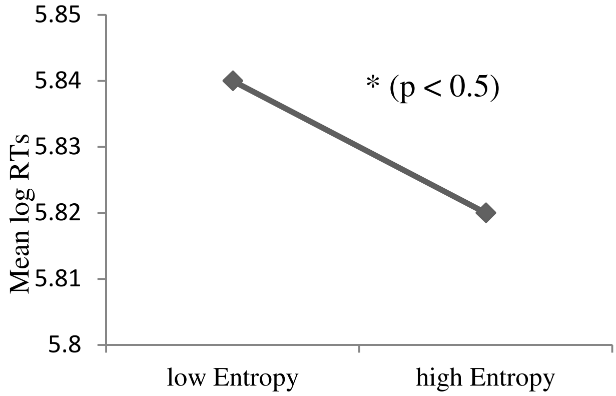
80 filler items, taken from another experiment, were used as distractors. 60% of the total 128 items were followed by a comprehension statement to ensure the participants were kept attentive to the task.

4.3. Results

Error rates in comprehension statements across subjects were <1%. Consequently, all collected reading times (RTs) were analyzed. RTs were transformed in a logarithmic scale to approximate normality, and the outliers exceeding 3SDs were removed (< 1%). Log-transformed RTs were analyzed in each region using repeated measures ANOVA and multi-level analyses with item and participant as random factors. The results presented below are significant at a level of $\alpha=.05$ or smaller.

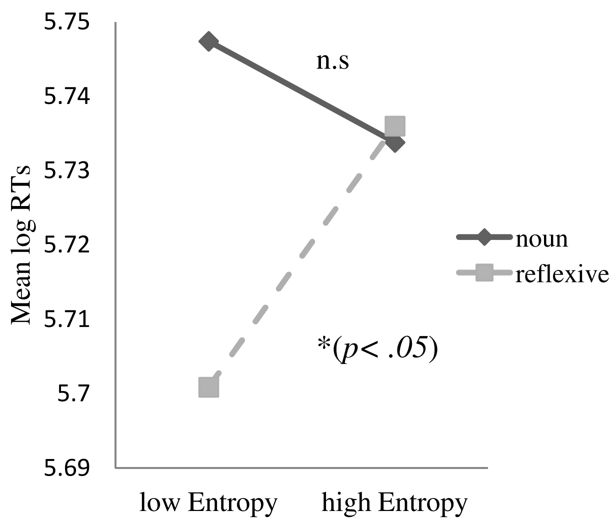
Verbs of high inflectional entropy are retrieved faster than those of low inflectional entropy. In fact, there was a main effect of entropy group ($p<.05$, effect size: $r = 0.35$), one region after the verb (rg 3) as demonstrated graphically in Figure 2.

Figure 2: Effect of inflectional entropy at the region of verb retrieval (rg 3)



Furthermore, inflectional entropy modulates object interpretation in a different way, depending on whether the object is a reflexive or a proper noun, as revealed by the statistically significant interaction between entropy and object type ($F(1,44) = 5.248$, $p<.05$, effect size: $r = 0.43$) in spill over region 9 (Figure 3).

Figure 3: Interaction between inflectional entropy group and object type (rg 9)



Post hoc tests attribute this effect to the processing of reflexives ($p<.05$); a reflexive in the object position is integrated faster when the preceding verb belongs to a low entropy paradigm. Processing of the nominal phrase (e.g. *Kathrin*) does not differ as a function of verbal entropy.

One should keep in mind that the higher the inflectional entropy of an inflected verb type's paradigm, the faster the type's retrieval. The re-accessing of the verb type, needed only in cases of intra-sentential dependencies, reverses the effect; the higher the inflectional entropy of the type's paradigm, the slower the processing of the reflexive. The reversal of the influence depicts, as will be explained in the next section, the different processes involved in retrieval of an item and in the re-accessing of that item.

5. Discussion

The answers to our research questions, as provided by the experimental results, are:

A1: The speed of integrating referentially-dependent elements like *zichzelf* does differ in accordance with whether *zichzelf* is integrated with a *praise*-type verb (low inflectional entropy) or a *help*- type verb (high inflectional entropy) and,

A2: Inflectional entropy influences only the speed of integration of lexical items that require intra-sentential dependencies and not that of lexical items that do not require such a dependency.

Why do verbs which are easy to activate (high inflectional entropy) cause delay when they are re-accessed?

The answer to this question comes from how activation works and follows the principle: "what is easier to activate is harder to re-access". We hypothesize that a lexical item that is activated quickly and easily creates a memory trace that is weaker than the one created by a lexical item that is harder to activate. Subsequently, re-accessing a lexical item with a weaker trace is more costly than re-accessing a lexical item with a stronger (more "prominent") memory trace. It is reminiscent of the FAN effect, which explains the brain's ability to keep easy access to and activate fast the items that are closely connected in a network. In contrast, re-accessing any of the items of the network takes longer time when the network is multiply connected and established (Anderson, 1974; Slamecka & Graf, 1978; Wagner, et al., 1998).

Turning to sentence processing, and more particularly to verbs, the accessibility of the network depends on the number of connections (like in the FAN effect), in other words on how many members a paradigm has, but also on the relative difference of the costs of activation of each member in the paradigmatic network. The individual information load describes the strength of the memory trace of each inflected verb type and quantifies the cost related to its activation. The inflectional entropy describes the way the paradigm is organized and quantifies the energy that is lost whenever it is triggered and activated. Verb types belonging to paradigms where the probabilities of the relevant inflected types are more or less the same (high inflectional entropy) are accessed easily but need more cognitive resources in order to be re-accessed, because of the activation principle. The supplementary cost is reflected on the longer reading times for referentially dependent objects of high entropy verbs in the self-paced reading task. On the contrary, when the object is a nominal phrase, the verb does not need to be re-accessed and does not become relevant for object interpretation; hence, verbal complexity does not influence speed of processing.

Furthermore, and although this was not the primary focus of our study, our results give an important insight into the linguistic theories underlying interpretation of referentially-dependent elements. The fact that inflectional entropy, a property of the verb, modulates the processing speed of reflexives (and not of proper nouns as well), and given that the entropy of the subjects across the experimental items was kept constant, gives support to linguistic theories that assume that the interpretation of a reflexive requires an operation on the verb (Reinhart & Reuland, 1993; Reuland, 2011).

6. Conclusion

We assumed sentence processing to be taking place in (at least) three stages; the first is where lexical items are activated in LTM and become available to WM. The second is where lexical items are combined together into a structure and obtain semantic interpretation and the third is where discourse and world knowledge complete interpretation of the sentence. We quantified the complexity with which an inflectional paradigm is organized in LTM by calculating the verb's inflectional entropy, taking both frequency *and* syntactic functions into account, and showed (replicating previous studies) that when the paradigm is more evenly distributed (higher inflectional entropy), verb types are easier to activate. The contribution of our study is that we found that in cases where the interpretation of the object needs an intra-sentential source for its referent (reflexive), it is re-accessing the verb; the verb's complexity modulates the speed of processing of the referentially-dependent object (attested interaction of inflectional entropy with the object type). This stems from the architecture of language processing and the cognitive system's principles of optimizing available resources and supports the linguistic view that interpretation of a reflexive is achieved by reflexivization of the verb.

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Notes

[1] By definition, when the items of the set are identical, they have the same probability and entropy of the set equals individual information load. Note that this is the case that entropy can reach its maximum value.

[2] Actually, semantic interpretation is a computed in a level between 3 and 4 (Koornneef, 2008). For reasons of simplicity and, since the focus of this paper is not in the particular distinction between the two levels, we only make a “rough” partition and consider them as one.

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