Semantic constraints in reading:
An eye-tracking study of highly restrictive verbs in Italian

Veronica D'Alesio[*]
Sapienza University of Rome, Italy

Abstract

Predictability plays a major role in reading research as it's thought to strongly influence word recognition in cognitive models of eye movement. While it is broadly defined by the probability of a word appearing in a given context, experimental designs in text-based eye-tracking studies are usually centred around lexical combinations, thus conflating a rather wide range of linguistic phenomena, from statistical co-occurrence (e.g. collocations) to intrinsic semiotic properties of words (e.g. light verb constructions). Therefore, the question arises whether changes in processing costs can be explained solely by context. The present study investigated a specific class of verbs in Italian whose properties entail a restriction on the semantic field of their referent (e.g. *mangiare*, 'to eat') since previous studies within the visual world paradigm have shown anticipatory effects in similar cases. Forty-six native speakers of Italian took part in a text-based eye-tracking experiment, where 18 pairs of highly and weakly restrictive verbs were embedded in sentences with no prior informative context. Three areas of interest (Verb, Noun, Spillover) were inspected for early and late measures: weakly restrictive verbs and their referents showed increased total reading time, while no effect was found on the duration of first fixation. We interpret these results as an integration of the subsequent context, thus indicating that verbs behave differently depending on their intrinsic properties. In line with current approaches to categorization, we think that there is scope for future research on reading and language processing to explore gradience within traditional lexical categories.

Keywords
reading, predictability, eye-tracking, Italian, verb semantics

1. Introduction

In the last decades, eye-tracking literature has provided fundamental insights into language processing. One of its key points has been predictability, roughly explained as the effect on a word that stems from a highly constrained context: a word is deemed predictable if it has a larger chance of being produced in a blank space given the prior linguistic context.

Reading experiments have shown effects on several processing measures, e.g. first duration fixation and total reading time (Ehrlich and Rayner, 1981; Binder et al., 1999; Rayner et al., 2004a). In their thorough review, Clifton et al. (2007) also write about plausibility or anomaly, adding to semantic relations between words a sense of pragmatic well-formedness based on shared world knowledge. At the same time, in its broader meaning predictability has been approached in the visual world paradigm under the guise of anticipation, looking at fixations' location on an array of visual stimuli following an acoustic input (Chambers et al. 1998; Altmann and Kamide, 1999, 2007; Kako and Trueswell, 2000; Kukona et al. 2011; Sauppe, 2016). Although conceptually similar regarding their scope, the two strands of research seem to differ in their premises, namely what constitutes predictability. While for text-based experiments, cloze-test predictability – whether assessed through ratings (Balota et al., 1985) or cloze tests (Ehrlich and Rayner, 1981) – covered for a real definition, in the visual world studies the absence of text has called for more semantic-centred hypotheses, up to Altmann and Kamide's

[*] Address for correspondence: Veronica D'Alesio, Department of Modern Letters and Cultures, Sapienza University of Rome, 00185 Rome, Italy. Email: veronica.dalesio@uniroma1.it

claim (2007, p.515) that "Anticipatory eye movements do not reflect the unfolding language; they reflect an unfolding (mental) world". On the one hand, lexical access appears to be affected by the surrounding context, while on the other hand, intrinsic semantic properties of words come into play. In the reading literature, this latter aspect is more likely to be considered in issues related to the general plausibility of the sentence. However, even in perfectly plausible contexts, it has been observed that in some instances (e.g. collocations) the semantic and distributional properties of a word can affect the processing of a neighbouring element (among others, Siyanova-Chanturia, 2011; Sonbul, 2015).

Therefore, the question arises as to whether the linguistic context should be the only factor at play when it comes to predictability in reading, or whether the intrinsic traits of a word deserve more attention. The following literature review will summarize the main findings about anticipation and predictability in online processing using eye-tracking. Starting from that, the study will focus on verbs, arguing that their intrinsic properties, as well as the gradient nature of traditional syntactic categories, need to be taken into account in reading experiments. Therefore, we will then briefly discuss some points on verb semantics in light of recent linguistic theories, aiming to see whether the syntactic category of Verb is fit to be used as a whole in experimental designs or if its semantic and discourse properties need to be accounted for.

2. Literature overview

In a pioneering study, Altmann and Kamide (1999) tested the effect of semantic information embedded in verbs on visual attention towards objects, by means of the now well-known duplet "the boy will *move* the cake/the boy will *eat* the cake". When presented with an array of objects before the acoustic onset of the noun, participants tended to look at the only object the semantic restrictions of the verb applied to (in the words of the authors, "the must-be-edible constraint"). In a previous experiment using the same paradigm, Chambers et al. (1998) investigated spatial prepositions (i.e. "inside", "below"): it is interesting to note that while restrictions could come from their closed-class status, their study revealed that participants did exploit a sort of mental representation depending on contextual references. Subjects were asked to put a cube inside a container, but when presented with a bigger cube, they only looked at containers that were large enough for the second cube.[1] Taken together these early studies suggest that semantic restrictions on an object do not come solely from the verb they're attached to, but the nature of the participants (as defined by their thematic roles) and perhaps other incidental contextual factors (shape, colours, distance, age, sex and so on) also play an important role in building up expectations.

Some authors call these traits "affordances", a word borrowed from Gibson (1977) and that is now widely used in experimental psychology to describe the set of properties of an object that are somewhat informative about the object's manipulation. Kako and Trueswell (2000) explore affordances in a study on verbs' semantic restrictions, using two conditions (weak restriction: *pick up*; strong restriction: *fold*) and one or no competitor for the related objects. In this way, participants' visual attention does not span over multiple objects, which themselves can carry other properties salient to the participant's perceptions (e.g. picking up the closest object, or the one a girl is more likely to choose, see also Kamide et al. 2003). Their results agree with previous studies, in that the condition of the strong restriction (e.g. *fold*) prompted earlier looks to the affordable object (e.g. *towel*), and when a second affordable object was present, strong restriction verbs led to an early inspection of the competitor as well. The authors discuss their results in the light of affordance matching and informativeness (Resnik, 1996): they argue that the two models are not mutually exclusive, since visual attention seems to be directed not only by informative verbs (i.e. strong condition) but also by weakly informative ones. It's likely that perception is guided by affordances but is then reinforced by informativeness in the case of strong selective verbs.

In a 2007 paper, Altmann and Kamide proposed another visual world study involving verbs: this time, the focus was on the event depicted by the linguistic input. They manipulated the tense of the verb, thus creating duplets of future vs. past tenses: according to the state of the event, participants showed anticipatory eye movements toward objects that had already undergone the process described, as is the case for empty or full glasses of wine (and beer) depending on the *will drink*/*has drunk* occurrences.

---

[1] Chambers et al. (1988) did not provide a time intercourse for their analyses of saccade movements, i.e. it is not possible to infer whether anticipation took place with respect to the acoustic input.

Expanding on the limits of affordances, Chambers and San Juan (2008) investigated properties that are not intrinsic to the object and that are rather connected to the communicative situation itself. The authors centred a series of experiments around the verb *return*, which implies a reference to something that has been moved. Using the visual world paradigm, they found anticipatory effects on the only object that was previously moved, and more interestingly, the effect decreased when an unrelated instruction was inserted between the movement scene and the target instruction. The authors interpreted this as a memory effect, clearly linked to the subject's episodic knowledge.

As we can see from the study of anticipatory movements, predictability seems to stem from at least three main sources: the object itself, with its intrinsic properties in terms of appearance, ends, usage, and manipulation; the event narrated (e.g. the agent-patient role in Suappa, 2016); the communicative situation in which the event is narrated (Chambers et al. 2008, experiments II and III on presuppositions and goals). For its multimodal approach, the visual world paradigm has proven to be a valuable tool for exploring contextual restrictions that go beyond the language level. Not surprisingly, in reading research contextual constraints are analysed in terms of linguistic context, highlighting thematic priming and semantic relations among words within a sentence or a paragraph. At the interface of production and comprehension, predictability plays a crucial role in co-occurrences, broadly defined as words that in each language usually go together. Predictability is usually defined as the chances of a word filling the blank space in a cloze test given the prior linguistic context, and it is thus achieved by ratings and scores based on actual cloze tests. We can easily see that predictability encompasses any set of lexical pairs – potentially including collocations, idioms, and binomials – as it's merely a measure of the statistical chance of co-occurrence, not adding much to the nature of the links between lexical units. In the study of collocations and co-occurrences, on the other hand, the probability of two words appearing together is usually computed by corpus-based measures, like frequency, transitional probability, and mutual information.

McDonald and Shillcock (2003a) analysed a set of 48 verb+noun(obj) combinations varying only in transitional probability – meaning the statistical probability of a word to be either followed or preceded by another word – and controlled for plausibility – that is, how well the meaning of a word fits into the semantic context of a sentence – and cloze probability. They found shorter first fixation durations (a metric traditionally related to predictability, see Ehrlich and Rayner, 1981; Binder et al., 1999; Rayner et al., 2004a) on the target noun, an outcome that prompted the claim that transitional probability is indeed independent of predictability, being the combinations all equally plausible and inserted in context-neutral sentences. The study was later replicated by Frisson et al. (2005), who conducted two experiments: in the first one they used the same verb+noun(obj) combinations from McDonald and Shillcock (2003a), and in the second one they kept 30 of these combinations and added 26 more items that better matched in cloze probability. In both experiments, high-transitional probability and low-transitional probability items were inserted in constraining context and neutral context sentences. Results from Experiment I essentially replicated those of McDonald and Shillcock (2003a), while Experiment II showed a larger sensitivity to context rather than transitional probability. The authors do not exclude that transitional probability could play a role in reading but at the same time, their outcomes point to a clear dependence of transitional probability from the broader measure of predictability, meaning that it'd be hard to find the former without the latter. Here again, we see that at the heart of the debate lies the source of predictability, given that it may either arise from the context or from the combination itself (i.e. transitional probability). Going more in detail, McDonald and Schillcock (2003a;2003b) argued that transitional probability is independent of predictability, and it manifests itself particularly in the early stages of processing, whereas the latter would account for decreasing in late measures. Moreover, the authors found facilitatory effects on first fixation and gaze duration also for the backward transitional probability, that is the corpus-driven statistical probability that a given word *n* is preceded by another word *n-1* (citing their example, *year* would have a higher backward transitional probability than *picture*, with respect to *last*). In their replication study, Frisson et al. (2005) initially observed roughly the same results (even though the effect was stronger on gaze duration than on first fixation duration) but, wanting to expand more on the correlation between transnational probability and predictability, they carried out the second experiment, with a much more controlled context. Given the same three AOIs that are used in the present study (as we will see in §4), no significant nor near-significant effect was found on the verb, while both gaze duration on the noun and first fixation duration

on the spillover were significantly affected by the most constraining context, thus showing predictability overriding transitional probability.

3. Considerations on verb semantics in reading

One of the remarks that prompted Frisson et al. (2005) to add new items for the second experiment was that the original set of items (the one used in McDonald and Shillcock, 2003a) contained a number of combinations that the authors referred to as "idioms", e.g. "cast doubt", "pay tribute", "save face". While they replaced these items, they kept some others that are not any less problematic, such as "lay claim", "draw attention", and "meet demand". Moreover, one could argue that neither "cast" nor "draw" are used idiomatically in these expressions but rather maintain a certain degree of transparency with one of their meanings ("throw" and "attract" respectively), being both polysemous verbs. However, we think that there might be reason to believe that the discrepancies found between the two experiments – at least in part – lay in the intrinsic properties of the verbs. In addition to polysemous verbs, there are a number of light verbs in both experiments, but especially in the second one: among the items added by Frisson et al. (2005), we found "make mistakes", "take decisions", "keep records", "give evidence". This construction type always sees a generic verb carrying tense and aspectual information, and a noun bearing the semantic representation of the event.

Research on collocations commonly refers to semantic transparency, pointing out that collocations are multi-word units whose meaning does not result from the meanings of their sub-units. As fruitful as this concept is, it certainly fits some collocations better than others: it's hard to say whether light-verb constructions like "take a photograph" or "have breakfast" are semantically opaque, mainly because they're semantically unbalanced, rather than opaque. Nonetheless, a great number of light-verb constructions are rightfully regarded as collocations in corpus-based approaches, which greatly value frequency and mutual information. Most importantly, light verbs are, by definition, context-dependent, as they are semantically empty in certain combinations, and in most cases, light verb constructions take the overall meaning from the noun. This is critical for at least two reasons: from a general theoretical perspective, the use of light verbs in context-related conditions is tautological; from a strictly methodological perspective, expecting to find facilitatory effects on the noun – like decreased first fixation durations or increased skipping rates – would be paradoxical since, as the meaning-bearing item, it's probably the noun that would require the most processing effort. Therefore, we believe that especially text-based paradigms need to acknowledge the shift from traditional syntactic classes to gradient categories, which is generally established in many of the current linguistic theories gravitating around the interface between lexicon and grammar (Ross, 1972; Hopper and Thompson, 1984; Croft, 1991, 2001; Aarts, 2007). When this heterogeneity is taken into consideration, the exclusive role of context in computing predictability may be brought into question.

More specifically, the question arises whether context affects equally each and every member of a given word class, or whether subtypes may enhance some level of predictability as well. This study is a preliminary investigation into fully-fledged lexical verbs, focusing on their behaviour in prior neutral contexts depending on whether or not they entail restrictions on the semantic field of their referent. We will refer to them as highly restrictive verbs, such as "write", "hear", and "wear" (these are also listed in Frisson et al.'s (2005) second experiment, for example). It's easy to see that most of the time they require one semantically defined category of nouns, plus another small set of metonymical units, like in the items from the same work "obey orders/obey adults", "wear gloves/wear whites". Within the valency framework, traits of this kind are referred to as "semantic components": Götz-Votteler (2007) describes them as "components [that] do not depend on the meaning of the verb, but can be regarded as properties of the noun, i.e. they are noun-inherent". As we have seen in the visual world studies mentioned above, anticipatory effects on highly restrictive verbs reveal an earlier access to a certain category of nouns relative to another semantic class of items, but how the selection among competitors belonging to the same group works is less clear.

4. The present study

Our study aims to investigate the processing of semantic restrictions of Italian verbs while reading verb-noun(obj) combinations. Evidence from visual word studies has shown that highly restrictive verbs lead to anticipatory eye movements toward the target object. This result is interpreted as an early lexical

access, occurring before the onset of the acoustic input of the noun. The visual world paradigm, however, doesn't tell us about the processing effort spent on the noun.

Our first research question will be whether semantic restrictions of verbs influence the following noun. Given three possible outcomes – no effect, facilitatory effect, and increased processing effort – our next research question will be whether there is a correspondence between the anticipation found in visual world studies and the processing effort in reading. Specifically, within this paradigm lexical access in reading is thought to take place in the first stages of processing. Contrary to previous text-based studies on predictability, where the target object was controlled on cloze probability or statistical occurrences, the manipulation here will happen on the verb, according to its gradient restricting condition. As we will explain in detail in the material section, we will compare two types of lexical verbs and sort them out between low-restrictive verbs (*sposta la torta*, 'move the cake') and highly restrictive verbs (*mangia la torta*, 'eat the cake'). The combination will be inserted in prior neutral contexts and the verbs will be matched for length, while frequency effects will be evaluated in the data analysis, based on single word frequency in common logarithm (the reference corpus is Paisà, available at www.corpusitaliano.it). Following the previous literature on predictability in reading research, we will consider total reading time (i.e. the total duration of fixations) and the duration of the first fixation on three areas of interest: verb, noun, and a spillover region of at least 5 characters (Balota et al., 1985). Thus, our third research question will be whether the typical predictability metrics used in text-based research show an effect in our study as well. Since in the sentence that we use there is no prior informative context, the results will be discussed in the light of the comparison between cloze probability and semantic motivation. We hypothesize finding facilitatory effects on nouns following highly restrictive verbs and higher processing costs on nouns following weakly restrictive verbs, reflecting the supposed presence of semantic traits that may be already encoded in the verb.

4.1 Participants
Forty-six students took part in the experiment, of which 40 were females and 6 males (age range: 20-31; mean age: 24). They were all native speakers of Italian with normal or corrected to normal vision. All participants were bachelor's or master's students enrolled at the Sapienza University of Rome and were rewarded with a school supply kit.

4.2 Procedure
The experiment was carried out using a screen-based eye-tracker (Tobii Pro Lab, v.1.118, sample rate 600 Hz). Participants sat at approximately 60 cm from the screen and were provided with a chinrest to avoid head movements. The trial consisted of 36 critical stimuli spaced off by 24 fillers: participants were asked to read silently and then move on to the next sentence by clicking the mouse button. Three AOIs were drawn over the noun, verb, and a spillover region of each critical stimulus: for each AOI we considered the duration of the first fixation and the total reading time, to account for early and late stages of processing respectively. Sentences were written in an 18-point monospaced font (Courier New), and calibration was performed on a 9-point grid.

4.3 Materials
In analysing verb+noun(obj) constructions, we considered lexical verbs only, an open class of verbs characterized by their predicative function, as opposed to copulative, auxiliary, and light verbs which realize more of a grammatical function. Following our research questions, we divided lexical verbs into strongly restrictive verbs (SV) and weakly restrictive verbs (WV). First, we selected SVs based on their definition in the Treccani online vocabulary (www.treccani.it/vocabolario), regarding as strong verbs those whose definition includes a clear reference to a specific object (e.g. *mangiare: "ingerire, inserire nell'organismo alimenti solidi e semisolidi*", 'to eat: to ingest […] solid or semisolid *food*'). From this list of verbs, we excluded those whose transitive sense is rare or scarcely used in contemporary Italian (e.g. the transitive use of *abitare*; 'to live in'). Since several studies (among others, Siyanova-Chanturia, 2011; Sonbul, 2015) observed shortened reading times in idioms and collocations, special attention was paid to avoid sequences of such kind. Weak verbs were also checked on the Treccani online vocabulary: these verbs have one or more very specific meanings with an undefined object (e.g. "*perdere: cessare di possedere qualche cosa*"; "*guardare: dirigere gli occhi, fissare lo sguardo su qualche oggetto*", 'to

lose: to stop owning something'; 'to watch: to point the eye gaze or to fixate the eyes on some object'). Note that "object" and "person" were considered differently: when verbs called for "object(s)" in general, we took it as a weak restriction, given the potentially infinite set of concrete and imaginary objects available; when verbs called for *persona/e* ('people'), we took it as a strong restriction, as it stands for a living being, usually a human (in our list, this was the case for *incontrare* and *salutare*; 'to meet' and 'to greet'). Finally, the 18 verbs within each duplet were matched by length, allowing for a maximum of 2 exceeding characters. Sentences were created to fit in one line of text to avoid vertical eye movements; furthermore, the linguistic context prior to the combination was meant to be as neutral as possible, and the five letters following the noun phrase – which would constitute the spillover region – were identical between paired items. Finally, combinations were never placed right before punctuation marks, for a twofold reason: first, to minimize risks of wrap-up effects; then, to allow for a spillover region to be taken as an area of interest.

Table 1. List of verbs classed in the strong condition vs weak condition

Strong verb	Ref (Object)	Weak verb	Ref (Object)	Selected noun
Suonare	*suono, strumenti musicali*	*prendere*	*cosa o persona*	*chitarra*
'To play'	Sound, musical instrument	To take	Object or person	guitar
Cucinare	*vivande*	*tagliare*	*corpo*	*carne*
'To cook'	food	To cut	Body (i.e., object)	meat
Ballare	*ritmi musicali*	*evitare*	*cosa o persona*	*valzer*
'To dance'	Musical rhythm	To avoid	Object or person	Walzer
Mangiare	*alimenti*	*spostare*	*cosa*	*torta*
'To eat'	food	To move	object	cake
Cucire	*pezzi di tela, di panno*	*guardare*	*oggetto, cosa*	*vestito*
'To sew'	Canvas, cloth	To watch	Object, thing	dress
Bere	*liquidi*	*comprare*	*oggetto, bene, proprietà*	*tisana*
'To drink'	liquids	To buy	Object, goods, properties	herbal tea
Versare	*somma di denaro*	*perdere*	*cosa*	*soldi*
'To pour'	Amount of money	To lose	thing	money
Leggere	*testo scritto o stampato, segni grafici*	*aprire*	*oggetto, cosa, parti del corpo*	*libro*
'To read'	Written or printed text, graphic signs	To open	Object, thing, body parts	book
Versare	*liquido*	*togliere*	*Nessun referente*	*latte*
'To pour'	liquids	To remove	No referent	milk

Scrivere **'To write'**	*segni grafici* Graphic signs	*iniziare* To begin	*azione* action	*articolo* article
Salutare **'To greet'**	*persona* person	*sconvolgere* To shock	*nessuno* No referent	*postino* mailman
Incontrare **'To meet'**	*persona* person	*preferire* To prefer	*cosa o persona* Thing or person	*bambini* children
Ascoltare **'To listen'**	*parole o persone* Words or people	*associare* To match	*Nessun referente* No referent	*musica* music
Coltivare **'To grow'**	*terreno, pianta* Land, plant	*eliminare* To remove	*Nessun referente* No referent	*pomodori* tomatoes
Assaggiare **'To try'**	*alimenti* food	*calpestare* To step on	*nessuno* No referent	*prugne* plums
Pettinare **'To comb'**	*capelli* hair	*aggiustare* To fix	*oggetto* object	*capelli* hair
Indossare **'To wear'**	*indumento, vestito* Clothes, dress	*portare* To bring; to have (on)	*qualcosa, qualcuno, capi di abbigliamento* Something; someone; clothes	*maglietta* T-shirt
Sgualcire **'To crease'**	*Indumenti, fogli di carta* Clothes, paper	*cambiare* To change	*Cosa o persona* Thing or person	*gonna* skirt

Note: *Ref(Object)* refers to the noun object(s) listed in the Treccani online vocabulary as referents of the verb. English translation in italics.

5. Data analysis and results

Analyses were implemented with R software (The R Core Team, 2022; Version 4.1.3) and the R software packages lme4 and lmerTest (Version 1.1-28; Bates, Maechler, Bolker, & Walker, 2015), fitting a linear mixed-effects model (Baayen, Davidson, and Bates, 2008) to each metric (Duration of first fixation, hence DFF; Total duration of fixations, hence TDF) for each AOI separately (Verb, Object, Spillover). Each time, we started from the most complex model, considering as fixed effects Condition (Strong vs Weak Verb), and Frequency (in common logarithm). As for the spillover region, consisting of more than one small word and/or function words, Frequency was not considered. We included both random intercepts and slopes for Subject, Item, and Length. For each AOI and metric, this initial model resulted in a singular matrix, suggesting a correlation issue in the chosen random effects. We then proceeded to perform a principal component analysis (Bates et al., 2015) in order to select the appropriate random structure for each model, which eventually consisted of the intercepts of both Item and Subject each time. The only exception was the model for the total duration of fixations on the Verb, which only included the intercept for Subject. Finally, we excluded the interaction between the two fixed factors, as it did not improve the fit of the model (based on the comparison of the Information Criteria through ANOVA). The final models for the duration of the first fixation and the total duration of fixations are shown in Table 2 and Table 3 respectively. We can see from the data that the R^2 is generally

low. However, this is not considered an uncommon scenario when dealing with rather isolated linguistic phenomena (Ellis and Larsen-Freeman, 2006).

Table 2. Duration of first fixation

Verb

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	2.42874	0.18435	41.74745	13.174	<2e-16	***
Condition WV	0.10642	0.07247	35.48599	1.468	0.1508	
Frequency	-0.10030	0.04591	35.48599	-2.185	**0.0356**	*

R² 0.1135251

Object

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	1.941e+00	1.644e-01	2.182e+01	11.804	6.07e-11	***
Condition WV	9.221e-02	5.896e-02	1.592e+03	1.564	0.118	
Frequency	3.290e-02	4.173e-02	1.759e+01	0.788	0.441	

R² 0.06375984

Spillover

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	1.675e+00	1.516e-01	4.591e+01	11.053	1.57e-14	***
Condition WV	1.159e-01	9.915e-02	1599e+03	1.169	0.243	

R² 0.1273448

No significant effect was found on the duration of the first fixation for any class of item, except for frequency in verbs. This is not surprising since this variable is known to affect early measures of processing, especially in the first stage of lexical access, where words are being recognized: we see that on the Verb region frequency displays a negative tendency, meaning that the more frequent the verb, the less time it will take to be processed.
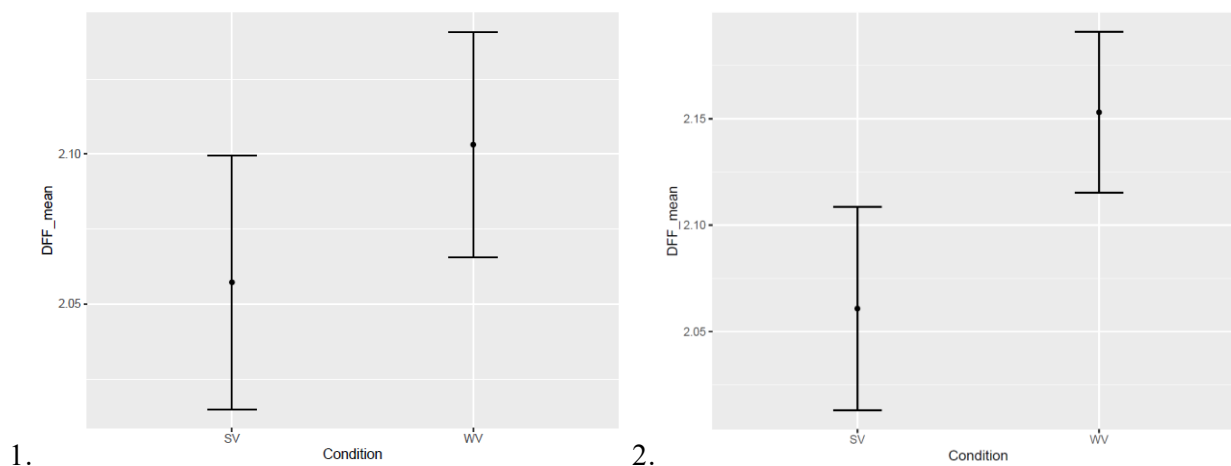

Figure 1. The effect of Condition on the duration of first fixation on Verb (1) and Object (2).

Table 3. Total duration of fixations

Verb

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	2.98028	0.21950	42.16984	13.577	<2e-16	***
Condition WV	0.14622	0.08607	35.46865	1.699	0.0981	.
Frequency	-0.14143	0.05452	35.46865	-2.594	**0.0137**	*

R² 0.1583748

Object

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	2.231e+00	1.551e-01	1.013e+01	14.381	1.01e-10	***
Condition WV	1.356e-01	6.094e-02	1.610e+03	2.226	**0.0262**	*
Frequency	2.045e-02	3.817e-02	1.610e+03	0.536	0.5922	

R² 0.08231431

Spillover

Predictors	Estimate	Std.Error	df	T value	Pr(>|t|)	
Intercept	1.9032	0.1709	42.6807	11.139	3.27e-14	***
Condition WV	0.1390	0.1011	1598.9988	1.376	0.169	

R² 0.1510683

Similarly to what we saw for the early measure, Frequency significantly affects the total reading time of verbs, showing a negative tendency here as well. However, the most interesting result can be observed on the Weak Condition, which appears to play a much bigger role in the later stages of processing: we observe a significant influence on the noun and a trend towards significance on the verb. No effect was found in the spillover region.
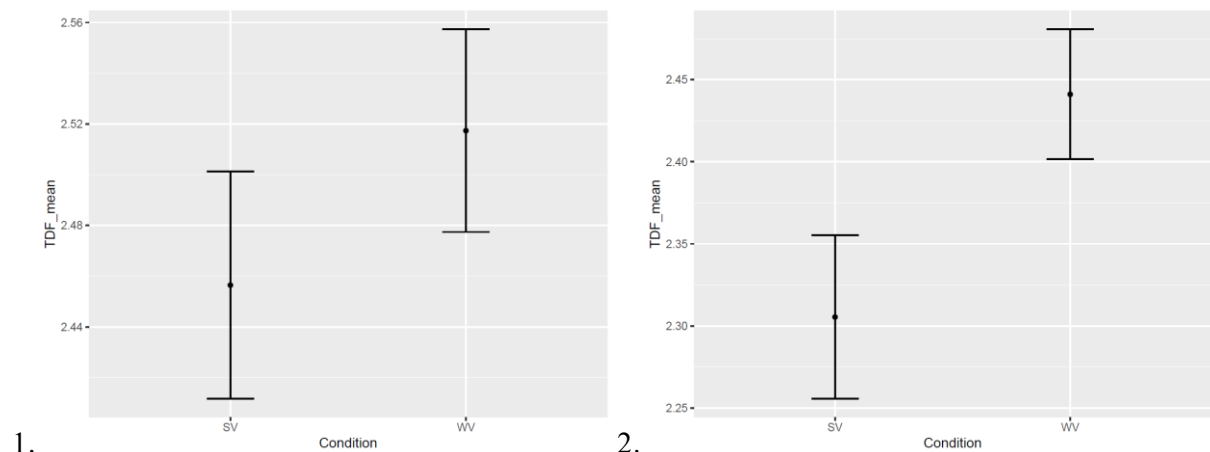

Figure 2. The effect of Condition on the total duration of fixations on Verb (1) and Object (2).

6. Discussion

The primary goal of the experiment was to ascertain whether semantic restrictions of verbs have an influence on the following noun(obj), hypothesizing that nouns whose traits were partially encoded in the verb preceding them needed less processing time and vice versa. This appears to be confirmed by our analyses, which indicate increased processing times of nouns and verbs in the weak verb condition. Crucially, the effect only arises in total reading time, perhaps suggesting a later integration of the following context. Early measures, in our case the first fixation duration, are considered to be reflective of early access to the word, thus being most influenced by frequency and familiarity (Clifton et al.,

2007). In our study, indeed, Frequency significantly affects the first fixation duration on verbs: at this point, participants are recognizing the word, and lexical factors are the most relevant. Subsequently, the effects of Condition are evident in the total duration of fixations, where we observe a significant influence on the noun, thus confirming our predictions. It is worth noting that a positive trend is showing on the verb as well, meaning that the less restricting verbs take more time to process. Since we explicitly avoided light verb constructions, we can rule out the incidence of polysemy and ambiguity (as found in Duffy et al., 1988; Kambe et al., 2001; Sereno et al., 2006; Rayner et al., 2006). Moreover, the effect being present in the late measure only, it might be that the interpretation of the strong verb+noun(Obj) combination is more straightforward and does not necessarily need further re-readings, easing the comprehension already at the first pass reading.

This brings us to our second research question, namely whether the anticipation advantage found in visual world studies could be seen in a text-based study as well. Most certainly, we must keep in mind that the two experimental paradigms are inherently different, as they work on different kinds of stimuli and rather different eye-tracking measures. Nonetheless, the sentences used in this study were designed to explore with text the affordances known to be relevant in visual word studies (especially in Altmann and Kamide (1999), whose "move the cake/eat the cake" has been literally transferred onto this experiment). Although we didn't find any early processing advantage, as Rayner et al. (2004b) observe, the discrepancy with respect to visual word studies may stem from the multiple-choice given to participants in these types of design, and this could hold especially true in cases where the target word in reading belongs to an open class. Kako and Trueswell (2000) aimed at investigating the time course of semantic-driven lexical selection, by providing participants with a competitor belonging to the same semantic field as the target object. This setting prompted early looks at both the target object and the competitor, suggesting rapid access to the verb meaning constraining the referential domain. What their results seem to point at, adding to other studies such as Altmann and Kamide (1999), is the initial selection of a semantic field, which would eventually be integrated leading to a later specific target selection. If this was the case, we would have expected to find immediate facilitatory effects in our strong condition, where the semantic field of the referent is defined by the verb. While our study agrees on the predictive nature of semantic restrictions, in our case verbs that could be considered more informative about their referent do not yield any early processing advantage on the noun. One the other hand, weakly restrictive verbs and their referents appear to be re-visited and re-assessed during text reading, contrary to the items in the Strong Condition. Another point to be considered is that visual attention may be driven by a preference for plausibility, which surfaces more starkly when dealing with hybrid or picture-based stimuli. In this sense, language may allow for larger semantic flexibility and entail a higher threshold of tolerance compared to real-life objects, which are directly bound to the finite experience of sensory perception. Naming abstract entities and playing with odd combinations is an inherent faculty of words, therefore it is not surprising that semantic-driven selection doesn't immediately disrupt language processing. Rayner et al. (2004b), for example, found evidence of degrees of severity in plausibility violations working with written text stimuli and, broadly speaking, investigations on meaning within text-based experiments are more prone to draw mixed outcomes when compared to visual world studies.

Comparisons with reading studies will be addressed in our final research question, focusing on semantic restrictions in verb+noun(obj) sequences: as we briefly discussed in the literature overview, effects in the processing of adjacent words are usually explained by some level of predictability. The main difference with our study stands in the absence of early effects which, given the prior neutrality of context, suggests that the semantic traits of the verb alone don't make the following name easier to retrieve. What we do find instead is some sort of subsequent processing integration for the weakly restrictive verbs only, showing increased cognitive effort in the total reading time of the noun(obj) and, marginally, of the verb itself. Our data support the view that not all verbs are influenced by context equally, as we have seen that weakly restricted combinations tend to be re-assessed in light of the following context, whereas the strongly restricted combinations do not show any additional processing cost neither in early nor in later stages. We believe that the issue is particularly relevant because predictability is heavily implemented in some models of eye-control in reading, most notably the EZ reader. Fixation times provide an indication of when the eyes move and, in this case, highly predictable words are deemed to be read faster or even skipped (see also Rayner and Well (1996) on the predictability effect and Rayner (1998) for insight on eye-movement during reading). Based on

the results of the present study, we argue that, at least for verb+noun combinations, some semantic components of the verb could affect its degree of context dependence, meaning that verbs that do not anticipate affordances of their referents entail an increased cognitive load on said referent perhaps integrating information from context, hence the change in late measures. Another aspect that would be worth investigating is the fact that part of highly restrictive verbs (relative to the items used in this study, the majority of them) entails valency alternance, meaning that the number of arguments (i.e. syntactic valency) varies according to the context: in other words, transitive verbs like "eat", "read" or "dance" can (and often do) appear with no direct object. On the other hand, all our control combinations included transitive verbs that usually call for a mandatory direct object: costly processing in later stages could mirror this need of necessarily integrating a patient to make sense of the predication.

The main purpose of the present study was to shed light on the extreme variance that can be found in the same word class and how implementing gradience into text stimuli may have repercussions on context-related predictability effects. In doing so, we came across some limitations. Perhaps the major shortcoming of the present study is to be framed in experimental psycholinguistics more than it is in linguistic theories. Starting off from eye-tracking literature, the focus on verb semantics in the strictest sense is inevitably reduced. We attempted to bridge two experimental paradigms – visual world and reading studies – and relate their findings on verb+noun(obj) combinations to current views on linguistic categorization. Future research on this topic would undoubtedly benefit from further delving into specific taxonomies already existing in theoretical linguistics. On the other hand, studies on lexicon and grammar could in turn further explore online processing methodologies in validating critical aspects of cognition. Finally, we hope to address some methodological issues in the future. While this preliminary work served us to partially represent oppositions within the same word class, the present design didn't allow us to compare light and heavy verbs, since light verb constructions usually call for abstract referents, opposite to what happens for highly restrictive verbs. Moreover, to further assess the time course of processing in different types of predication, other early measures should be considered: although in our case the absence of spillover effects almost certainly rules out inflated early reading times on the preceding noun, measures of gaze duration could be taken into account when investigating lexical selection within restrained semantic fields.

7. Conclusion

This paper presents an eye-tracking experiment aimed at observing differences in reading times of words belonging to the same class. Over the years, linguistic theories have pushed for a change in the word class system, and today the traditional categories of Verb and Noun are not defined solely by their grammatical properties anymore but rather placed on gradient scales according to pragmatic, discourse, and semiotic factors. Eye-tracking research, on the other hand, has provided new insights into the processing of language, which is widely considered to be predictive in nature. From this perspective, we aimed to investigate the role of the semantic properties of the verb in relation to context. Eighteen highly restrictive verbs (i.e. verbs implying restrictions on the semantic field of their referent) were paired with 18 weakly restrictive verbs, and then inserted in sentences where the prior context was neutral, and the following was not. Contrary to what visual world studies and reading experiments found on anticipation and predictability, we didn't find any change in early measures, suggesting that the semantic properties of the verb alone didn't make the referent any more predictable. However, we observed a significant increase in the total reading time of the noun region (and a tendency for the verb region) in the weak verb condition. We interpreted this as a late integration of the following context, perhaps signalling further effort in tying the referent to its predicate. We discussed the results in comparison with two major eye-tracking experimental paradigms (visual world studies and text-based trials) and explained the discrepancies in light of current approaches to categorization, a much-debated topic in construction grammar and valency theory. The present study is intended as a preliminary investigation, hopefully evolving into a fine-tuned assessment of verb semantics by means of online processing techniques. Finally, one of the aims of the paper was to challenge predictability in reading as solely context-driven, arguing that the inherent properties of words should not be neglected: we think that there may be scope for future research to further delve into the relationship between lexicon and grammar in different environments.

References

Aarts, B. (2007). *Syntactic gradience: The nature of grammatical indeterminacy*. Oxford University Press.

Altmann, G. T., & Kamide, Y. (1999). Incremental interpretation at verbs: Restricting the domain of subsequent reference. *Cognition*, *73*(3), 247-264. https://doi.org/10.1016/S0010-0277(99)00059-1

Altmann, G. T., & Kamide, Y. (2007). The real-time mediation of visual attention by language and world knowledge: Linking anticipatory (and other) eye movements to linguistic processing. *Journal of Memory and Language*, *57*(4), 502-518. https://doi.org/10.1016/j.jml.2006.12.004

Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, *59*(4), 390-412. https://doi.org/10.1016/j.jml.2007.12.005

Balota, D. A., Pollatsek, A., & Rayner, K. (1985). The interaction of contextual constraints and parafoveal visual information in reading. *Cognitive Psychology*, *17*(3), 364-390. https://doi.org/10.1016/0010-0285(85)90013-1

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, *67*(i01). https://doi.org/10.18637/jss.v067.i01

Binder, K. S., Pollatsek, A., & Rayner, K. (1999). Extraction of information to the left of the fixated word in reading. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(4), 1162. https://doi.org/10.1037/0096-1523.25.4.1162

Chambers, C. G., Tanenhaus, M. K., Eberhard, K. M., Carlson, G. N., & Filip, H. (1998). Words and worlds: The construction of context for definite reference. In *Proceedings of the twentieth annual conference of the Cognitive Science Society* (pp. 220-225). Routledge.

Chambers, C. G., & San Juan, V. (2008). Perception and presupposition in real-time language comprehension: Insights from anticipatory processing. *Cognition*, *108*(1), 26-50. https://doi.org/10.1016/j.cognition.2007.12.009

Cicalese, A. (1999). Le estensioni di verbo supporto. Uno studio introduttivo. *Studi Italiani di Linguistica Teorica ed Applicata*, *28*(3), 447-485.

Clifton Jr, C., Staub, A., & Rayner, K. (2007). Eye movements in reading words and sentences. *Eye Movements*, 341-371. https://doi.org/10.1016/B978-008044980-7/50017-3

Croft, W. (1991). *Syntactic categories and grammatical relations: The cognitive organization of information*. University of Chicago Press.

Croft, W. (2001). *Radical construction grammar: Syntactic theory in typological perspective*. Oxford University Press on Demand. https://doi.org/10.1093/acprof:oso/9780198299554.001.0001

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language*, *27*(4), 429-446. https://doi.org/10.1016/0749-596X(88)90066-6

Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during reading. *Journal of Verbal Learning and Verbal Behavior*, *20*(6), 641-655. https://doi.org/10.1016/S0022-5371(81)90220-6

Ellis, N. C., & Larsen-Freeman, D. (2006). Language emergence: Implications for applied linguistics—Introduction to the special issue. *Applied Linguistics*, *27*(4), 558-589. https://doi.org/10.1093/applin/aml028

Frisson, S., Rayner, K., & Pickering, M. J. (2005). Effects of contextual predictability and transitional probability on eye movements during reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *31*(5), 862. https://doi.org/10.1037/0278-7393.31.5.862

Gibson, J. J. (1977). The theory of affordances. *Hilldale, USA*, *1*(2), 67-82.

Götz-Votteler, K. (2007). Describing semantic valency. In *Valency: Theoretical, Descriptive and Cognitive Issues*. De Gruyter Mouton. https://doi.org/10.1515/9783110198775

Gries, Th. S. (2015). The most under-used statistical method in corpus linguistics: Multi-level (and mixed-effects) models. *Corpora*, *10*(1), 95-125. https://doi.org/10.3366/cor.2015.0068

Hopper, P. J., & Thompson, S. A. (1984). The discourse basis for lexical categories in universal grammar. *Language*, *60*(4), 703-752. doi:10.1353/lan.1984.0020.

Kako, E., & Trueswell, J. C. (2000). Verb meanings, object affordances, and the incremental restrictions of reference. In *Proceedings of the annual meeting of the Cognitive Science Society* (Vol. 22, No. 22).

Kambe, G., Rayner, K., & Duffy, S. A. (2001). Global context effects on processing lexically ambiguous words: Evidence from eye fixations. *Memory & Cognition*, *29*, 363-372. https://doi.org/10.3758/BF03194931

Kamide, Y., Altmann, G. T., & Haywood, S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, *49*(1), 133-156. https://doi.org/10.1016/S0749-596X(03)00023-8

Kukona, A., Fang, S. Y., Aicher, K. A., Chen, H., & Magnuson, J. S. (2011). The time course of anticipatory constraint integration. *Cognition*, *119*(1), 23-42. https://doi.org/10.1016/j.cognition.2010.12.002

McDonald, S. A., & Shillcock, R. C. (2003a). Eye movements reveal the on-line computation of lexical probabilities during reading. *Psychological Science*, *14*(6), 648-652. https://doi.org/10.1046/j.0956-7976.2003.psci_1480.x

McDonald, S. A., & Shillcock, R. C. (2003b). Low-level predictive inference in reading: The influence of transitional probabilities on eye movements. *Vision Research*, *43*(16), 1735-1751. https://doi.org/10.1016/S0042-6989(03)00237-2

Rayner, K., & Well, A. D. (1996). Effects of contextual constraint on eye movements in reading: A further examination. *Psychonomic Bulletin & Review*, *3*(4), 504-509.

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *124*(3), 372.

Rayner, K., Ashby, J., Pollatsek, A., & Reichle, E. D. (2004a). The effects of frequency and predictability on eye fixations in reading: implications for the EZ Reader model. *Journal of Experimental Psychology: Human Perception and Performance*, *30*(4), 720. https://doi.org/10.1037/0096-1523.30.4.720

Rayner, K., Warren, T., Juhasz, B. J., & Liversedge, S. P. (2004b). The effect of plausibility on eye movements in reading. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(6), 1290.

Resnik, P. (1996). Selectional constraints: An information-theoretic model and its computational realization. *Cognition*, *61*(1-2), 127-159. https://doi.org/10.1016/S0010-0277(96)00722-6

Ross, J. R. (1972, April). The category squish: Endstation hauptwort. In *Chicago Linguistic Society* (Vol. 8, pp. 316-328).

Sauppe, S. (2016). Verbal semantics drives early anticipatory eye movements during the comprehension of verb-initial sentences. *Frontiers in Psychology*, *7*, 95. https://doi.org/10.3389/fpsyg.2016.00095

Sereno, S. C., O'Donnell, P. J., & Rayner, K. (2006). Eye movements and lexical ambiguity resolution: investigating the subordinate-bias effect. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(2), 335. https://doi.org/10.1037/0096-1523.32.2.335

Siyanova-Chanturia, A., Conklin, K., & Schmitt, N. (2011). Adding more fuel to the fire: An eye-tracking study of idiom processing by native and non-native speakers. *Second Language Research*, *27*(2), 251-272. https://doi.org/10.1177/0267658310382068

Sonbul, S. (2015). Fatal mistake, awful mistake, or extreme mistake? Frequency effects on off-line/on-line collocational processing. *Bilingualism: Language and Cognition*, *18*(3), 419-437. https://doi.org/10.1017/S1366728914000674