



Language Processing Evidence for Linguistic Structure

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Abstract: This article illustrates how data from language processing experiments might bear on theoretical linguistic issues and controversies. Based on the results from real-time processing studies of subject raising vs. subject control structures and successive-cyclic *wh*-movement in English, and of long-distance scrambling in Japanese, this article examines how language processing data can help shed light on the nature of the linguistic representations of different types of non-canonically ordered sentences.

Keywords: *Language processing, English, Japanese, scrambling, wh-movement, raising, control.*

Resumen: Este artículo ilustra cómo datos provenientes de experimentos de procesamiento del lenguaje pueden arrojar luz sobre algunos temas (algunos controvertidos) relacionados con la teoría lingüística. Basado en los resultados de estudios de procesamiento a tiempo real de estructuras de ascenso de sujeto vs. estructuras de control de sujeto y movimiento sucesivamente cíclico en inglés, así como desplazamiento libre (*scrambling*) de larga distancia en japonés, este artículo examina cómo los datos de procesamiento del lenguaje pueden ayudar a dilucidar la naturaleza de las representaciones lingüísticas de distintos tipos de oraciones ordenadas de forma no canónica.

Palabras clave: *Procesamiento lingüístico, inglés, japonés, scrambling, movimiento qu-, ascenso, control.*

Resumo: Este artigo ilustra de que forma dados experimentais do processamento de linguagem podem ser suportados por questões linguísticas teóricas e por controvérsias. Com base nos resultados de processamento em tempo real em estudos de subida de sujeito vs. estruturas de controlo de sujeito e movimento *wh*- sucessivo cíclico em inglês, e de *scrambling* de longa distância em japonês, este artigo analisa a forma como os dados de processamento de linguagem podem ajudar a esclarecer a natureza das representações linguísticas dos diferentes tipos de orações não-canónicas.

Palavras-chave: *Processamento de linguagem, Inglês, Japonês, scrambling, movimento wh-, subida, controlo.*





1. Introduction

Grammatical theory and description have traditionally relied, to a large extent, on informally gathered intuitive judgements. This has prompted methodological criticism from other cognitive science disciplines as well as from some linguists (Ferreira 2005, Wasow & Arnold 2005, Gibson & Fedorenko 2010, to name but a few). Consider, for instance, the following quote from Ferreira (2005: 370), whose criticism specifically targets Chomsky's (1995, and later) *Minimalist Program* (MP):

[...] the empirical foundation for the MP is almost exclusively intuition data obtained from highly trained informants (i.e., the theorists themselves). Data from other areas such as neurolinguistics, computational linguistics, and psycholinguistics were not taken into account at all, nor were any insights from the rest of the cognitive sciences. Of course, this was true of other theoretical shifts in generative grammar, but it is particularly striking today given the broad range of methods now available for studying language.

While Ferreira's assessment may seem unduly harsh, and singling out the MP from the set of current grammatical frameworks not obviously justified (see e.g. Marantz 2005), there is nevertheless some truth in her remarks. However, things are looking up in that a growing number of theoretical linguists have started broadening their methodological inventory. Although borrowing methods from other cognitive science disciplines does not necessarily help resolve theoretical controversies or help us decide between alternative grammatical formalisms, any such moves towards extending theoretical linguistics' empirical base should presumably be welcomed.

One way of improving linguistic data collection methodology is to use formally gathered judgement data from larger numbers of non-biased informants (compare e.g. Bard, Robertson & Sorace 1996, Schütze 1996, Cowart 1997 – but see Phillips 2009 for a defence of informal judgements). Somewhat reassuringly, for linguists who lack the resources or expertise for running larger-scale acceptability judgement experiments, there is evidence suggesting that informal judgements tend to concur with experimentally gathered ones (compare e.g. Sprouse & Almeida 2012).¹

¹ This is not necessarily the case for data gathered using timed or speeded judgement tasks, however (see e.g. Staum Casasanto & Sag 2008, Radford, Felser & Boxell 2012).





Whereas the importance of controlled experiments to improve the validity of grammaticality judgements is fairly widely acknowledged (Featherston 2005, Alexopoulou & Keller 2007, Fanselow & Féry 2008, Radford et al. 2012, to name but a few), many theoretical linguists are skeptical about the importance of real-time processing experiments for grammatical theory-building. This article aims to show that sentence processing data can indeed provide important insights for linguistic theory (see also Felser *in press* for a more comprehensive review and discussion). Linguistic theories seek to characterise our linguistic knowledge, and linguistic knowledge is what underlies our ability to process language. Experimental psycholinguistic techniques such as cross-modal priming, reading-time measurements or event-related brain potentials allow us to chart the moment-by-moment processes involved in sentence comprehension and can provide a window on syntactic structure-building or dependency formation as it occurs (for detailed descriptions of these methodologies, see e.g. Nicol & Swinney 1989, Just, Carpenter & Woolley 1982, Kaan 2007, Staub & Rayner 2007).

Although invisible or inaudible elements – such as silent copies assumed to be left behind by syntactic movement - cannot be made visible directly, appropriately designed processing tasks allow us to observe their effects on sentence comprehension (Nicol & Swinney 1989, Gibson & Warren 2004, among many others) or production (e.g. Franck, Soare, Frauenfelder & Rizzi 2010). Silent syntactic constituents have traditionally played an important role in generative-transformational grammar, whereas non-transformational or lexicalist frameworks typically make do without them (compare e.g. Sag & Fodor 1994).

The primary aim of this article is to illustrate how data from language processing tasks can provide insights into the nature of syntactic representations and thus help broaden the empirical base of linguistic theory. I will present three example studies here, each making use of a different experimental methodology, all of which are drawn from research that I was involved in during my time at the University of Essex. Study 1 examined long-distance scrambling in Japanese and yielded results which bear on the question of VP configurability in so-called ‘free word order’ languages (Nakano, Felser & Clahsen 2002). Study 2 looked at processing reflexes of successive-





cyclic wh-movement (Marinis, Roberts, Felser & Clahsen 2005) and study 3 provides reading-time evidence for structural differences between two superficially identical types of infinitival complement constructions (Batterham 2009).

2. Study 1: VP configurationality

Our first example illustrates how processing data may bear on the question of whether or not verb phrases in free word order languages have a configurational structure. Japanese, for example, is well known for permitting highly flexible ordering of argument phrases, illustrated in (1) below, with (1a) representing the canonical ordering and (1b-f) showing non-canonical or *scrambled* word orders.²

- | | | | | | |
|-----|----|--------|--------|--------|---|
| (1) | a. | NP-NOM | NP-DAT | NP-ACC | V |
| | b. | NP-NOM | NP-ACC | NP-DAT | V |
| | c. | NP-DAT | NP-NOM | NP-ACC | V |
| | d. | NP-DAT | NP-ACC | NP-NOM | V |
| | e. | NP-ACC | NP-NOM | NP-DAT | V |
| | f. | NP-ACC | NP-DAT | NP-NOM | V |

Generative-transformational accounts of scrambling have typically claimed that non-canonical word orders are derived from canonical ones via leftward syntactic movement (Saito 1985, Nemoto 1995, among others). However, the derivation of 'short' (or clause-bound) scrambling structures as in (1) is theoretically controversial. As an alternative to movement-based analyses, it has been suggested that the various possible word orders in (1) may be base-generated. Some base-generation accounts assume that Japanese verb phrases have a 'flat' rather than a configurational structure, which then allows for arguments to be merged and assigned thematic roles in any order in principle (Hale 1980, Farmer 1984). Another type of base-generation account assumes that scrambled arguments are initially merged into non-thematic positions - for instance, as IP adjuncts - but subsequently undergo LF movement (i.e. lowering) into VP-internal thematic positions (Bošković & Takahashi 1998). Typically, both leftward movement and lowering accounts assume that Japanese VPs are configurational, with silent copies (or unfilled thematic positions) serving as

² Japanese is a case marking language (NOM = nominative, DAT = dative, ACC = accusative, GEN = genitive).





placeholders for scrambled constituents. Non-configurational accounts, in contrast, do not assume scrambled arguments to be linked to any configurationally determined, unfilled slots within VP.

From a left-to-right processing perspective, fronted constituents must be held in working memory until a corresponding 'gap' can be identified further downstream in the sentence. There is ample evidence suggesting that, when processing non-canonical word orders (notably, those involving A'-movement), the processor actively searches for a gap (Frazier & Clifton 1989). When a suitable gap is encountered, the fronted element is retrieved from memory and mentally reconstructed at this point, and (ultimately) linked to its subcategoriser or other lexical licenser (compare e.g. Gibson 1998).³ Psycholinguistic experiments can provide indirect evidence for syntactic movement, for example by measuring its effects on real-time processing or comprehension difficulty. The underlying rationale here is that processing filler-gap dependencies is hypothesized to be computationally more costly than processing canonical or base-generated word orders. Although formal linguistic theories do not normally make any claims about processing, sentence processing research has found robust reflexes of filler-gap dependency formation and of relative processing difficulty being affected by, among other things, the complexity of the constituent extracted from (Gibson 1998). Reading-time studies of short scrambling have thus far yielded mixed results, however, with only some reporting evidence of scrambled word orders being more difficult to process than canonical ones (see Sekerina 2003 for review and discussion). It is conceivable, for instance, that, even if clause-internal word order variations like those shown in (1b-f) are created through movement, any corresponding differences in processing difficulty are too small to consistently yield measurable effects.

Another line of experimental research has investigated the hypothesized mental reconstruction of moved constituents at specific structural positions.

³ The term 'gap' is commonly used in the psycholinguistic literature to refer to unfilled structural positions or 'missing' arguments in non-canonically ordered sentences. It does not necessarily correspond to any specific theoretical notions such as 'trace' or 'copy'. Fronted constituents are frequently referred to as 'fillers', again so as to remain maximally neutral with respect to particular linguistic formalisms.





Nakano et al. (2002) report the results from two cross-modal-priming experiments which examined the mental reactivation of fronted constituents at hypothesized preverbal gap positions in Japanese. In this experimental paradigm, participants are asked to make simple lexical (e.g. word/non-word) decisions to visually presented target words while listening to pre-recorded sentence stimuli (Nicol & Swinney 1989). The rationale here is that visual word recognition should be facilitated for words that are identical or semantically related to the sentence constituent currently being processed. The constituent of interest is usually either an overt or a covert anaphor, and any antecedent priming effects observed during the processing of an anaphoric element are taken to be indicative of real-time dependency formation. Comparing reaction times to target words presented at different points during the sentence allows us to examine, for example, whether fronted constituents are mentally reactivated at specific structural positions.

Two alternative proposals have been made in the sentence processing literature as to how the mental reconstruction of fronted constituents might be accomplished. They roughly correspond to the theoretical controversy between configurational or movement-based accounts on the one hand, and non-configurational or lexicalist accounts that do not posit any silent syntactic constituents on the other. The first hypothesis, often referred to as the *trace reactivation hypothesis*, claims that displaced constituents are linked to their lexical subcategoriser indirectly via silent syntactic constituents (e.g. Bever & McElree 1988). The *direct association hypothesis*, on the other hand, claims that displaced constituents are integrated into the thematic grid of their subcategoriser directly via lexically based association, without being mentally reconstructed at specific structural positions (e.g. Pickering & Barry 1991). For languages with head-final VPs such as Japanese or German, these two competing hypotheses give rise to different predictions for cross-modal priming. Trace-based reactivation should yield reactivation effects *before* listeners had the chance to fully process the lexical subcategoriser, as they should mentally reconstruct the fronted element at the preverbal gap position on the basis of their knowledge of the configurational VP structure, and independently of lexical-semantic properties of the verb. Direct association, in contrast, predicts that reactivation effects should be triggered by the subcategorizing verb.





The auditory materials used in Nakano et al.'s main experiment were sentences involving long-distance scrambling of direct object NPs as in (2) below. Unlike short scrambling structures such as those in (1) above, which show characteristics of both A- and A'-movement, long-distance scrambling out of finite clauses shows typical characteristics of A'-movement (compare e.g. Saito 1992).

- (2) Suruto, **remon-o**, [CP futari-me-no hito-ga shikai-sha-ni,
and then lemon-ACC the second person-NOM M.C.-DAT
[CP sono kodomo-ga onna-no hito-ni **gap**i nedatte-iru to] kotae-ta]
that child-NOM female person-DAT asking COMP] answered]
'And then, a lemon, the second person answered to the Master of Ceremonies that that
child was asking the woman for.'

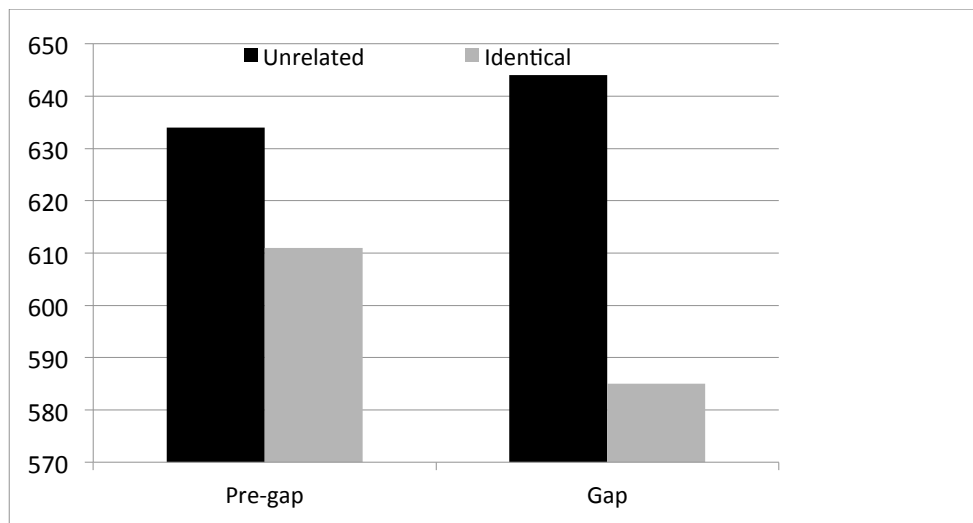
In (2), the direct object of the most deeply embedded verb *nedatte-iru* 'asking', the accusative-marked NP *remon-o* 'lemon', has been scrambled to the left edge of the highest clause. The position marked 'gap' indicates its hypothesized thematic base position. Visual target words that were either identical or unrelated to *remon* were presented at one of two points during the sentence, at the hypothesized gap position or at a control position 500ms earlier. Long-distance scrambling was chosen here to increase the relative difficulty of mentally reconstructing the fronted constituent at the tail of this dependency compared to short scrambling, so as to maximize the chance of obtaining measurable reactivation effects.

The results showed that the recognition of visual target words identical to the head of the scrambled noun phrase was indeed facilitated at preverbal gap positions compared to earlier (pre-gap) control positions, and also compared to the recognition of unrelated words (see Figure 1 below).





Figure 1. Mean lexical decision times (in ms) for unrelated and identical targets at pre-gap and gap test points, for the high working memory participants in Nakano et al.'s (2002) study.



This indicates that the scrambled object was mentally reactivated at its canonical structural position, i.e. at the offset of the dative NP *onna-no hito-ni* ‘female person’ in example (2) above, and before participants had the chance to fully process the clause-final subcategorising verb. The observed position-specific reactivation effect was restricted to participants who had scored relatively highly in an independently administered working memory test, however. Nakano et al. speculate that this might have been due to the stimulus sentences’ unusually high degree of structural complexity and the relatively high task demands, which may have prevented participants with a reduced working memory capacity from successfully recovering the fronted constituent at its canonical position.

Note, however, that the above finding does not by itself provide unequivocal evidence for preverbal structural gaps, or support for movement accounts. It is conceivable that all of the verb’s arguments are routinely reactivated when the subcategorizing verb is processed (or possibly even before, if the verb can be anticipated), as predicted by the direct association hypothesis, which would be a lexically, rather than a structurally, driven effect and also be consistent with non-configurational or flat structure accounts. To test whether preverbal antecedent priming effects are also observed for distant but non-scrambled arguments, Nakano et al. carried out a further cross-modal priming experiment to see whether subject arguments are mentally reactivated as well. The materials included canonically ordered sentences like (3) below, in which





the nominative-marked subject NP *ooji-ga* 'prince' was separated from the verb by two intervening argument phrases.

- (3) Homon-saki-no byoin-de, ooji-ga kodomotachi-ni
visit-place-GEN hospital-in prince-NOM children-DAT
omocha-o # age-ta
toy-ACC give-PAST
'In the hospital he visited, the prince gave the children some toys.'

The results showed no evidence of the subject being reactivated at the preverbal test point (marked #). The lack of reactivation effects in Nakano et al.'s second experiment is surprising from the point of view of the direct association hypothesis, which predicts reactivation of all the verb's arguments when the verb is encountered, rather than the selective reactivation of syntactically displaced ones. Instead, this finding is what we would expect from the point of view of configurational accounts, according to which the word order in (3) corresponds to the order in which the three argument phrases were originally merged, and under the assumption that Japanese VPs are head-final.

Together, the two cross-modal priming experiments described above lend support to movement-based approaches to scrambling and to configurational accounts of Japanese verb phrases, and are difficult to reconcile with non-configurational or lexicalist accounts (compare also Clahsen & Featherston 1999, for German). Note, however, that Nakano et al.'s (2002) results are unable to differentiate between, for example, leftward movement and lowering accounts, as both of these would predict position-specific, preverbal antecedent reactivation effects.

3. Study 2: Processing reflexes of cyclic movement

Our second example also looks at operator movement across more than one sentence boundary, but this time focussing on intermediate structural gaps. Transformational accounts of *wh*-movement have usually assumed that 'unbounded' movement must proceed successive-cyclically (Chomsky 1973, and later). In a multi-clausal sentence such as (4) below, for example, the relative pronoun *who* (coreferent with the matrix subject *the tourist*) is thought to originate as the object of the most deeply embedded verb, *angered*. Rather than being shifted to its surface position in a single step, however, fronted *wh*-elements are assumed to make intermediate stops before crossing certain types





of major phrase or clause boundaries, leaving behind silent copies of themselves (or 'gaps', to again use a more theory-neutral term) every time this occurs.

- (4) The tourist [_{CP} *who*_i the guide claimed [_{CP} *gap*_i that the hotel manager had

 angered *gap*_i]] wants to return home now.

Under this view, the relative pronoun in example (4) will move in at least two steps, with an intermediate copy (or additional gap) left behind at the left edge of the embedded CP.⁴ In non-transformational theories of grammar, a SLASH or GAP feature is often assumed to indicate an unresolved dependency (compare e.g. Levine & Hukari, 2004; Pollard & Sag, 1994, for *Head-Driven Phrase Structure Grammar*). There is a large body of cross-linguistic descriptive evidence in support of successive-cyclic movement, including the observation that in some languages, long *wh*-movement appears to leave behind overt copies of the moved constituent at intermediate landing sites (see e.g. Felser 2004). It has been suggested however that unbounded movement can also apply in one fell swoop (Postal 1972), or that certain types of fronted *wh*-phrase are either exempt from cyclic movement (Pesetsky 1987, Rizzi 2003) or base-generated in their surface position (van Craenenbroeck 2010).

From the point of view of left-to-right language processing, and given that our mental computational workspace is limited, successive-cyclic movement would appear to be a good thing as it helps break up long dependencies into a series of local, and thus more manageable, steps. Data from processing tasks allows us to examine, in principle, whether a fronted constituent is indeed carried forward as a series of small steps or moved in one fell swoop. Using similar experimental materials as Gibson & Warren (2004) did in an earlier study, Marinis et al. (2005) investigated the processing of English sentences that contained a potential intermediate landing site such as (4) above, contrasting them with sentences like (5) below which did not.

- (5) The tourist [_{CP} *who*_i [_{DP} the guide's claim about the hotel manager] had
 angered *gap*_i] wants to return home now.

⁴ Within Chomsky's (2000, 2001) phase-based theory, such intermediate stops are a consequence of the *Phase Impenetrability Condition*, according to which constituents can only cross phase boundaries from the edge of each (CP or transitive *vP*) phase they are to be extracted from.



In (5), there is no option but for the relative pronoun to move in one fell swoop, on the assumption that the intervening complex DP does not provide an intermediate landing site for the pronoun at its edge. Two further non-movement conditions (6a,b) were added to control for any potential effects of the structural difference between (4), which contains an embedded CP, and (5), which contains an embedded complex DP, independently of movement.

- (6) a. The tourist believed [_{CP} the guide claimed [_{CP} that the hotel manager had angered everybody in the holiday party]].
b. The tourist believed [_{CP} [_{DP} the guide's claim about the hotel manager] had angered everybody in the holiday party].

Marinis et al. used a non-cumulative self-paced reading paradigm, which involves segment-by-segment visual presentation of the stimulus sentences at a speed controlled by the participants themselves (Just et al. 1982). Elevated reading times at a particular segment (compared to an identical segment in another experimental condition) are taken to indicate increased processing difficulty. For sentences such as (4) vs. (5), the main prediction was that if readers make use of the intermediate landing site available in (4) when carrying forward the fronted relative pronoun *who*, this should facilitate the pronoun's integration with its subcategoriser, the verb *angered*, when this verb is finally encountered.

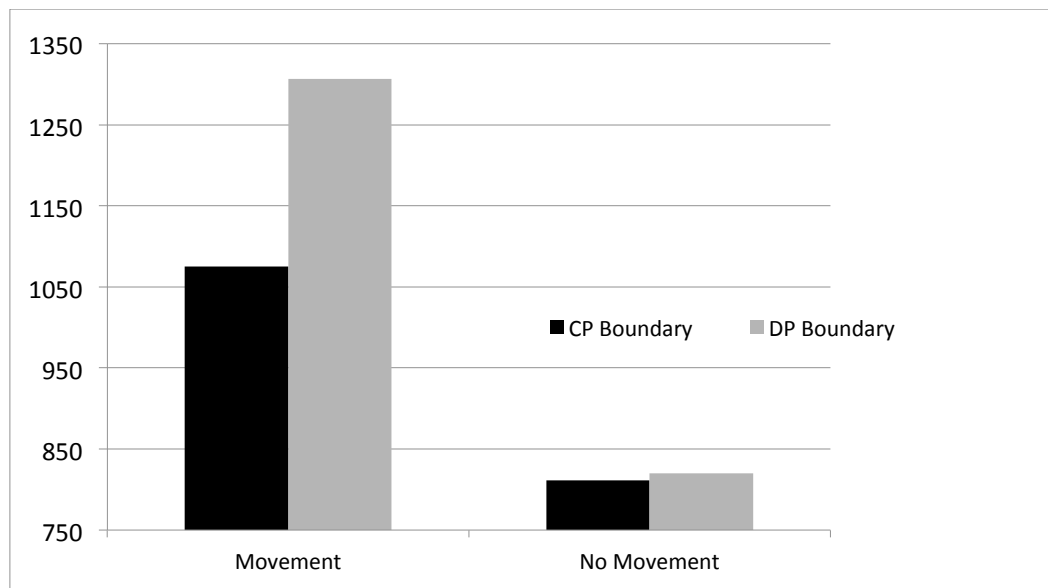
The results confirmed this prediction, replicating earlier findings by Gibson & Warren (2004). Shorter reading times were observed at the segment containing the subcategorizing verb for sentences like (4), which contained an intermediate landing site, in comparison to (5), which did not, as shown in Figure 2 below.⁵ Importantly, no significant reading-time difference was found between the two non-movement control conditions (6a,b), which confirms that the observed processing advantage for intermediate gap sentences at the subcategorising verb was not due to any differences in the two critical sentences' syntactic structure or complexity *per se*.

⁵ Marinis et al. (2005) also examined different groups of non-native speakers, whose reading time patterns differed from the pattern shown by the natives. Discussing the possible sources of these differences here, however, would lead us too far astray.





Figure 2. English native speakers' mean reading times (in ms) at the subcategorising verb region for sentences involving *wh*-movement across a CP or DP boundary and for corresponding non-movement sentences in Marinis et al.'s (2005) study.



There was also a tendency for reading times to be longer for the complementiser *that*, which marks the lower CP boundary, in (4) compared to (6a) (825ms vs. 729ms), which may reflect the additional processing effort required for mentally reactivating the fronted *wh*-element at this point. As in Gibson & Warren's earlier study, this numerical trend did not reach statistical significance, however.

Marinis et al.'s (2005) and Gibson & Warren's (2004) results provide processing evidence for the successive-cyclic nature of long *wh*-movement, which complements and extends the existing body of non-experimental evidence.⁶ Although the above results are incompatible with the idea that *wh*-fronting in structures like (4) happens in one fell swoop, note that they cannot necessarily help us decide between alternative formalisations of cyclic movement in different grammatical frameworks. Among the open questions which processing data could potentially help address, however, is the question

⁶ This includes morphophonological reflexes of successive-cyclic movement such as *wh*-agreement in Irish (McCloskey 2001) and Chamorro (Chung 1982) or tonal downstep in Kikuyu (Clements, McCloskey, Maling & Zaenen 1983), *wh*-copying in a variety of typologically different languages (Felser 2004, and references cited therein), and children's use of medial *wh* in complex questions in English (Thornton, 1990).





of whether referential (or *d-linked*) *wh*-phrases differ from pronominal ones in being able to move – or to reconstruct – in a single step.⁷

4. Study 3: Subject raising vs. subject control

Our final case study compares the processing of two superficially identical types of sentences containing subjectless infinitives. The question of whether or not subject control (7a) and subject raising sentences (7b) share the same syntactic representation and derivational history continues to be a much debated issue in theoretical linguistics (compare Kirby, Davies & Dubinsky 2010).

- (7) a. Emma tried to smile.
b. Emma seemed to smile.

In both (7a) and (7b), the understood subject of the infinitive *to smile* is referentially identical to the matrix subject *Emma*. Despite their superficial similarity, control constructions as in (7a) differ from raising constructions as in (7b) in a number of semantic and syntactic properties (see e.g. Dowty 1985, Rooryck 1992, Hornstein 2003, Kirby et al. 2010). For example, only raising – but not control – predicates can have expletive subjects, preserve the idiomatic meaning when combined with idioms, and show voice transparency when passivized (Hornstein 2003: 7f.). Within the generative tradition, it is usually assumed that subject control but not subject raising verbs assign a thematic role to their grammatical subject (e.g. Chomsky 1981). There is considerable disagreement among formal linguists, however, as to whether (and if so, how) these differences are also reflected in the way control and raising sentences are derived syntactically.

Within the government-and-binding variant of generative-transformational theory (Chomsky 1981), it is assumed that subject control involves an anaphoric dependency between the matrix subject and the understood subject of the matrix verb's infinitival complement, a phonetically null pronominal element conventionally labelled *PRO* (compare 8a). The derivation of raising structures, on the other hand, has traditionally been

⁷ See Frazier & Clifton (2002) for some evidence of processing differences between referential and non-referential *wh*-phrases.





assumed to involve argument movement, i.e. movement of the subject from a thematic to a non-thematic argument position, as shown in (8b) (where strikethrough indicates the silent copy left behind by movement).

- (8) a. Emma_i tried [PRO_i to smile]
 b. Emma seemed [~~Emma~~ to smile]
 ↑

Others however have argued that (7a) and (7b) share the same syntactic representation and derivational history. This would be the case if either (i) control and raising verbs differ in their lexical properties only, with neither of the sentences in (7) involving any movement (e.g. Bresnan 2001, Culicover & Jackendoff 2006), or (ii) the derivation of both (7a) and (7b) involves argument movement (e.g. Hornstein 1999).

From the point of view of left-to-right processing, these competing theoretical possibilities each suggest different processing patterns for control vs. raising sentences. If subject control and subject raising sentences differ only in their (or the matrix verb's) semantic complexity, then control sentences should be more difficult to process than raising ones, all other things being equal. In contrast, if computing raising sentences involves an additional syntactic operation, such as argument movement (or its equivalents in other grammatical frameworks), then raising sentences should be more difficult to process than control sentences. That is, we might expect a non-thematic or 'raised' subject to be carried forward in search for a corresponding gap (the processing equivalent of movement; compare sections 2 & 3 above), which should incur a processing cost, whereas the subject of control verbs should stay put.

Batterham (2009) reports the results from an eye-movement monitoring experiment designed to test the above predictions. This experimental technique allows for fairly natural stimulus presentation while providing a particularly fine-grained record of moment-by-moment processing (Staub & Rayner 2007). Participants' eye movements were recorded while they read brief stories such as (9) below, the critical sentences of which contained either a subject control or a raising verb.

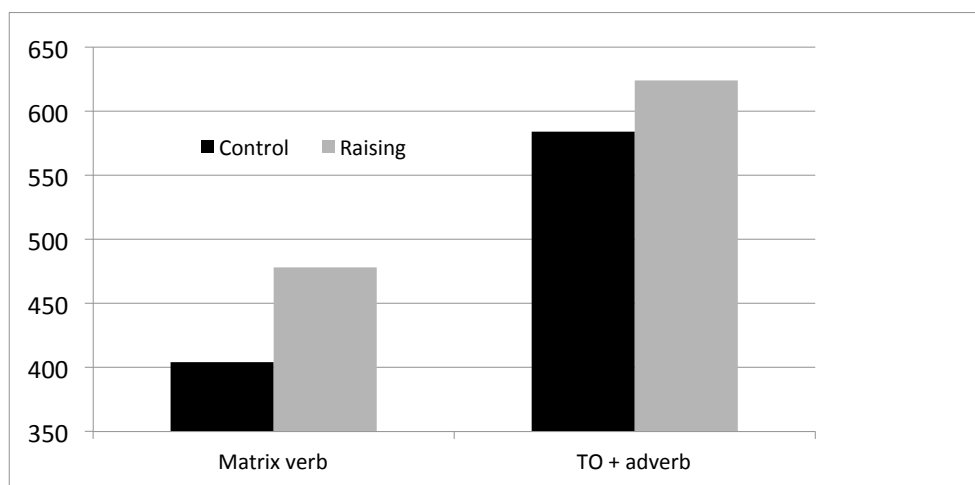
- (9) Comedy is a tough business. The comedian in the pub *tried* (*seemed*), after a wobbly start, to quite confidently work with the loud and rowdy audience. By the end of the set they were on his side.



The two sets of verbs chosen were carefully matched for length, frequency, lexical decision time and subcategorisation bias. A 'padding' adverbial was added between the matrix verb and the infinitival marker so as to create some distance between the control or raising verb and the point at which it became clear to participants that the sentence contained a subject-less infinitive. As with the self-paced reading technique described above, higher reading times at a particular region of interest are thought to index increased processing difficulty.

The analysis of the eye-movement data revealed that raising sentences tended to elicit higher reading times than control sentences (significantly so in several eye-movement measures) from the matrix verb onwards up until the start of the infinitival region. At no point did the control sentences elicit significantly higher reading times than the raising sentences. Figure 3 below shows participants' mean total reading times at two points of particular interest, the matrix verb and the beginning of the infinitival region.

Figure 3. Mean total reading times (in ms) at the matrix verb and beginning of the infinitival region for control vs. raising sentences in Batterham's (2009) experiment 3.



Considering that subject raising verbs are semantically less complex than subject control verbs, the observation that raising verbs - and the regions following them - are nevertheless more difficult to process than control verbs or sentences is unexpected. If control and raising sentences like (7a,b) differed only in their semantic complexity (i.e. the number of thematic roles involved), we would have expected to see the opposite pattern to that shown in Figure 3, with semantic complexity effects reflected in higher reading times for control compared to raising sentences.





Instead, Batterham's results support theoretical accounts that maintain there is a difference in syntactic complexity between control and raising sentences. The observed reading-time pattern is expected under the assumption that encountering a raising verb triggers the search for a subject gap further downstream, and the need to carry the (as yet theta-less) matrix subject forward during the processing of intervening sentence material. This incurs a measurable processing cost compared to sentences that contain a control verb, whose subject can be theta-marked locally and thus does not need to be carried forward.

In short, Batterham's (2009) results support theoretical accounts according to which subject raising and control sentences differ in their derivational history, with the derivation of raising sentences being computationally more complex than the derivation of control sentences (compare e.g. Chomsky 1981). They are also in line with the results of an earlier German study by Featherston, Gross, Münte & Clahsen (2000) which employed event-related brain potentials. Featherston et al. found evidence for increased processing difficulty for raising compared to control sentences at the beginning of the infinitival region, which they suggested reflected the greater processing difficulty associated with 'undoing' syntactic movement in the case of subject raising sentences. Note once again, however, that although the above results support theoretical accounts that syntactically distinguish between subject control and subject raising, they are not by themselves able to differentiate between different possible formalisations of any such syntactic complexity differences.

5. Concluding remarks

The three examples presented above showed how real-time processing data can help reveal subtle details of abstract linguistic structure. Study 1 provided evidence for the configurational structure of VP in Japanese, study 2 for the presence of intermediate syntactic structure in long *wh*-dependencies in English, and study 3 for the greater syntactic or derivational complexity of raising compared to control sentences. Other sentence types whose derivation has been investigated experimentally include *inter alia* sentences containing unaccusatives (Friedmann, Taranto, Shapiro & Swinney 2008), topicalisations



(Bader and Frazier 2005; Felser, Clahsen & Münte 2003), heavy NP shift (Staub, Clifton & Frazier 2006), subject movement (Koizumi & Tamaoka 2010) or verb movement (De Goede 2006). Processing experiments have, moreover, provided evidence for the 'mental reality' of abstract linguistic elements such as implicit arguments (Maurer, Tanenhaus & Carlson 1995) or parasitic gaps (Phillips 2006), and have also provided novel perspectives on the nature of island constraints (e.g. Kluender 1998, Wagers & Phillips 2009, Hofmeister & Sag 2010) and constraints on anaphoric binding (Koornneef, Avrutin, Wijnen & Reuland 2011). While it is of course unrealistic to expect every theoretician to start carrying out processing experiments, the selective research review presented above is intended to encourage theoretical linguists to pay more attention to what goes on in language processing research and to acknowledge the potential usefulness of real-time processing data for linguistic theory building and evaluation.

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