Chapter 10
Syntactic Variance and Priming Effects in Translation

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Abstract The present work investigates the relationship between syntactic variation and priming in translation. It is based on the claim that languages share a common cognitive network of neural activity. When the source and target languages are solicited in a translation context, this shared network can lead to facilitation effects, so-called priming effects. We suggest that priming is a default setting in translation, a special case of language use where source and target languages are constantly co-activated. Such priming effects are not restricted to lexical elements, but do also occur on the syntactic level. We tested these hypotheses with translation data from the TPR database, more specifically for three language pairs (English-German, English-Danish, and English-Spanish). Our results show that response

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times are shorter when syntactic structures are shared. The model explains this through strongly co-activated network activity, which triggers a priming effect.

Keywords Cognitive Effort • Priming • Eye Tracking • Translog • Literal translation • Co-activation • Keystroke Logging

10.1 Introduction

A range of single word studies have investigated the effect of translation ambiguity on behaviour during translation recognition and translation production. Tokowicz and Kroll (2007) noted that when their English-Spanish bilingual participants translated single word stimuli with more than one possible translation, their response times were slower in comparison to words with only a single translation. Tokowicz and Kroll attributed this effect to active competition between translation alternatives. A selection between all possible alternatives is cognitively effortful as all items have to be compared with regards to their appropriateness, and once the appropriate item has been singled out, others have to be suppressed.

Up to now, the effect of translation alternatives on behaviour during translation has been dominated by single word studies (e.g. Laxén and Lavaur 2010; Boada et al. 2012; Eddington and Tokowicz 2013). To the best of our knowledge, the first study to investigate behavioural measures for translations of whole texts is the one by Dragsted (2012). In her study, she found increased total reading time (on source text words), number of fixations (on source text words) and pauses in the production for words with high lexical variance. It therefore seems likely that processing of source text (ST) lexical items involves the activation of target language (TL) competitors. However, a raw count of the number of competitors does not directly reflect their influence on behavioural times, since some options may be more dominant than others, i.e. receive more neural activation. In the following, we will explain how such influence can be accounted for.

As a transfer process including the reproduction of an initial source message in another context, every translation is a selection of a final target formulation out of many possible target formulations (Neubert and Shreve 1992). However, the details of this selection process and the factors influencing it are largely unknown. Whenever an ST is translated by *n* translators producing TT_n translations, each single translation TT_i is selected out of many possible target texts. Each selection of the actual elements of TT_i is determined by the characteristics of the target language, its morphology, syntax, pragmatics and stylistics, the translation brief and target audience etc., but also by the individual translator, her background and experience. Each final target text TT_i is thus a selection from possible options in the target language which were available to one particular translator at one particular point in time. It is highly unlikely that any two translators will produce exactly the same translation of the same source text. In cases where every translator produces a different translation, one would assume the selection process to be cognitively demanding, as all possible realizations of TT elements are assumed to have been potentially available to all translators. In cases where all translations of a given source text unit are identical, this can be taken as a sign of lacking choice, as there might have only been a single correspondence in the target language. Consequently, the translation was comparatively easy as the translator did not have to make any choice. Translation competence can be defined in terms of selection and selection effort, namely as "the ability to generate a series of more than one viable target text (TT_1 , TT_2 ... TT_n) for a pertinent source text" and "the ability to select only one viable TT from this series, quickly and with justified confidence." (Pym 2003, 489). However, this does not imply that the selection process and its outcome are the same for all competent translators.

Based on the assumption that different translations created by different translators reflect the options which were available to all translators, Carl and Schaeffer (forthcoming; see also Chap. 9) describe this concept with the term of word translation entropy. Word translation entropy is also a feature in the TPR-DB which is described in Sect. 2.4.7.

The idea behind word translation entropy is that the distributions of the translation probability for each word should be a better predictor than the raw count of translation options. As some translation options can be chosen by more than one translator, such choice behaviour can inform about selection processes in translation. To account for the selection variance, translation entropy measures are higher when each translator produces a different translation and entropy values are low when only a limited number of translation alternatives have been realized. Entropy is a measure of uncertainty in choices.

We propose to use entropy as a measure of a translator's cognitive effort in making choices during translation. Carl and Schaeffer show that when the translation of a word resulted in a high translation entropy i.e. high variation, these words were also more effortful to process than words with low word translation entropy. This affected total reading times of the words on the source and of the target text. Schaeffer et al. (Chap. 9) also found an effect on first fixation durations and skipping probability (on source text words).

10.2 Entropy as a Measure of Variation

The notion of entropy in the sense it is discussed here is borrowed from information entropy and was introduced by Claude E. Shannon. He used the term as a description of the unpredictability or uncertainty of the content of messages. A high information entropy value indicates much uncertainty, which, when used to describe the translation process, represents a set of co-activated translation possibilities that are equally good choices for the translation of a source text item. Claude E. Shannon (1951) used the term information entropy as a measure of the amount of information that is transmitted in a communication process. "Variance" and "information" are interchangeable in this context (Miller 1956). Entropy increases when variation

Table 10.1 Example probability distributions of hypothetical translations. TT_1–TT_6 exemplify the effect of probability distributions on entropy (***H***)

	TT_1	TT_2	TT_3	TT_4	TT_5	TT_6	H
$p(s \to t_i)$	1.00						0.00
	0.50	0.50					1.00
	0.25	0.25	0.25	0.25			2.00
	0.50	0.16	0.17	0.17			1.79
	0.18	0.18	0.16	0.16	0.16	0.16	2.58
	0.30	0.14	0.14	0.14	0.14	0.14	2.51

increases. The concept of Entropy is denoted by the symbol ***H*** and represents the average amount of non-redundant information provided by each item entering a system. Entropy ***H*** is computed based on the probability ***p*** of an item entering the system and its information. The probabilities $\boldsymbol{p(s \to t_i)}$ of an ST item ***s*** and its possible translation $\boldsymbol{t_{i \ldots n}}$ are computed as the ratio of the number of alignments $\boldsymbol{s \to t_i}$ counted in TTs over the total number of observed TT segments, as in Eq. (10.1). The information of a probability p is defined as $\boldsymbol{I(p) = -\log_2(p)}$, and entropy ***H*** is the expectation of that information as defined in Eq. (10.2):

$$p(s \to t_i) = \frac{counts(s \to t_i)}{\#translations} \tag{10.1}$$

$$H = \sum\nolimits_{i=1}^{n} p_i I(p_i) = -\sum\nolimits_{i=1}^{n} p_i \log_2(p_i) \tag{10.2}$$

Table 10.1 describes the effect of probability distributions on entropy (***H***): if all six translators choose the same translation realization for a given word, the probability of this translation is at its maximum (6/6 = 1) and entropy is at its minimum (0), but as soon as translators opt for different target realizations, entropy increases: if one option has a probability of 0.30 and five other options have each a probability of 0.14, then entropy is relatively high (2.51). If there are four different options, but all four options have the same probability (0.25), entropy is higher than when one of the four options has a higher probability (0.50) than the other three (0.16, 0.17, 0.17). For example, the entropy value 2.51 calculated in the following way:

$$2.51 = -1^* \left(0.30^* \mathrm{LOG}_2 0.30 + 4^* \left(0.14^* \mathrm{LOG}_2 0.14\right)\right) \tag{10.3}$$

Instead of counting all possible translation alternatives for a given source item, entropy captures the weight of each of these alternatives and may hence be a better reflection of the cognitive environment of translators working on a given text. In other words, it captures the distribution of probabilities for each translation option, so that more likely choices and less likely options are weighted accordingly. The following section examines possible factors which might have an influence on entropy.

10.2.1 Co-activation and Translation

The first question to be addressed is the onset of the selection process and the effect of the selection process on eye movements during reading for translation. At what point during the translation process does the translator start with the mental production of the target text, and to what extent does this mental production process interfere with source text comprehension?

Studies suggest that both languages of a bilingual are always active. Grosjean (1997) argued that activation of the bilingual's two languages is situated on a continuum which has a relatively monolingual state at one extreme and highly co-activated bilingual state at its other extreme. Grosjean argued that it is the context of the language use which determines where on the continuum the bilingual is currently situated: if both interlocutors speak the same two languages, it is more likely that both languages are active, while when only one interlocutor speaks two languages or two interlocutors do not speak the same two languages, it is more likely that the bilingual(s) are situated closer to the monolingual mode. Translation would situate the bilingual firmly towards the very extreme of the bilingual state. A range of studies supports this hypothesis.

Macizo and Bajo (2006) presented professional translators and naïve bilinguals (Spanish/English) with single sentences containing interlingual homographs. In a masked self-paced reading paradigm, participants were instructed to either read the sentence for oral repetition or for oral translation. According to the condition, participants had to read the Spanish sentences and either translate them into English, or repeat them. The homographs made the sentence ambiguous when their meaning in the other language became activated: e.g. *presente* in Spanish is very similar to the English *present*. While the Spanish word is not ambiguous in the sentence, when translating it into the English word *present*, it could either refer to the present moment or to a gift. Macizo and Bajo found that the ambiguous homograph slowed down reaction times, but only when the purpose of reading was to translate. This effect was more pronounced for naïve bilinguals than for professional translators.

Ruiz et al. (2008) used essentially the same experimental design, but manipulated the frequency of the equivalent target word. They kept the monolingual frequency of critical words in the Spanish source sentence constant while the equivalent target words had either a high or a low frequency. Ruiz et al. found that reaction times were slowed down when the equivalent English target word had a low frequency, but again, this was only the case in the translation condition. We interpret their findings in terms of online parallel activation of source and target items during translation; i.e. both languages are active to a high degree during translation.

Schaeffer et al. (forthcoming) used a similar experimental design: this study compared reading for comprehension with reading for translation, but instead of self-paced reading, they used an eye-tracking paradigm. Furthermore, the authors manipulated the number of target words required to translate a single source word embedded in the same sentence frame. For example, *worry* and *laugh* were embedded in the same sentence frame (Many of the fishermen will *worry/laugh*).

Whereas the translation of *worry* into German requires three words *sich Sorgen machen*, *laugh* can be translated by a single word *lachen*. Schaeffer et al. found that the first fixation duration was 23 ms longer when more than one target word was needed for the translation. Again, this effect occurred only in the reading for translation condition. This study further supports the idea that translation occurs online and that target items are activated early during source text reading.

Wu and Thierry (2012) lend further support to the automatic co-activation of the two languages which they observed even though the experimental design discouraged it. In their ERP study, participants were asked to press a button in response to the presentation of circles or squares. Participants were told that sometimes words would appear on the screen, but were instructed to ignore these. 15 % of these words were interlingual homophones, i.e. their Chinese translation would sound similar to either of the words *circle* or *square*. Wu and Thierry found an N200 effect for these homophones, suggesting that participants had to inhibit their spontaneous reaction of pressing the button any time the English word activated the Chinese words for either *square* or *circle*. Thus, co-activation could be detected in an environment where it was explicitly discouraged and even irrelevant to the task. We therefore assume that both the ST and TT language are simultaneously activated during the entire translation process. That means that the translator becomes engaged in exploring and selecting potential target text elements as soon as she starts reading the source sentence. As both languages may be activated to the same degree, it is likely that they influence one another during this selection process. One form of this mutual influence is priming (see Sect. 10.2.3 below). In addition, given that in the studies by Bajo and colleagues, the effect was more pronounced for bilinguals than for translators, it is possible that translators are better able to control co-activation, due to their training and constant exposure to both languages simultaneously.

The question remains however, whether it is not more beneficial for translators to retain a specific source text construction if this is possible in the target structure. Such a strategy would be cognitively less demanding than the search of an alternative formulation. This question is addressed in the following section.

10.2.2 The Literal Translation Hypothesis

Like many other concepts in Translation Studies, the concept of literal translation is the object of various definitions (Chesterman 2011, 24). However, it is important to be able to quantify literality if the aim is to show that whatever effect is observed is not language specific, if the aim is to produce a model of translation which is language independent. Carl and Schaeffer (forthcoming) propose a definition of literality which allows for quantification of the phenomenon. According to their definition, a translation is literal when the following three literality criteria are fulfilled:

1. Word order is identical in the ST and TT.
2. ST and TT items correspond one-to-one.
3. Each ST word has only one possible translated form in a given context.

Literality criterion 3 is of particular interest as it refers to translation entropy. Expanding this criterion to syntactic features, we stipulate that the translations are structurally literal if an ST sentence is translated into the target language with a single syntactic structure by all translators in a given sample. Syntactic entropy measures the uncertainty that different translators will produce the same TT structure for a ST sentence. Syntactic entropy is an indicator for the literality of translations on a syntactic level, and we introduce syntactic literality to the three literality criteria above:

4. All translations of a given source sentence are translated into the target language with the same syntactic structure.

Thus syntactically literal translation would be one with syntactic entropy of 0. Using entropy measures, literality can be studied using a quantitative approach. In line with Ivir's (1981) notion of formal correspondence, literality has been associated with less cognitive effort than non-literal translations. Ivir (1981, 58) describes the translation process as follows:

> The translator begins his search for translation equivalence from formal correspondence, and it is only when the identical-meaning formal correspondent is either not available or not able to ensure equivalence that he resorts to formal correspondents with not-quite-identical meanings or to structural and semantic shifts which destroy formal correspondence altogether. But even in the latter case he makes use of formal correspondence.

Equally related to this notion of formal correspondence as employed by Ivir is Toury's (1995, 275) "law of interference" which postulates that "(. . .)in translation, phenomena pertaining to the make-up of the source text tend to be transferred to the target text." Similar to Ivir, Toury used this law of interference to posit that less cognitive effort is involved in the production of literal translations as they are a kind of "default setting" in the translating mind. In sum, we argue that the default option for a translator is to consider a literal translation which is more likely to be activated first due to a priming effect (see below) and we further argue that if the default is not acceptable or if other, less literal options are activated, this leads to more cognitive effort.

10.2.3 Priming and Variation in Translation

Priming is a psychological effect that affects language in response to stimuli so that the prior encountered element is repeated or processed faster. This effect has been observed in studies involving one language for semantic representations, but more relevant for the present purpose is that this has also been observed for structural representations in tasks involving one language (cf. Pickering and Ferreira 2008). In addition, there is some evidence that structural priming has also been observed in studies involving two languages, i.e., in cross-linguistic structural priming studies (e.g. Hartsuiker et al. 2004). These studies suggest that semantic and structural representations are shared between languages when these are similar in the two languages (e.g. Duñabeitia et al. 2010; Bernolet et al. 2013). It is likely though, that the mechanism underlying cross-linguistic structural priming requires a similar construction i.e. congruent word order in both languages (Hartsuiker et al. 1999; Hartsuiker and Westenberg 2000; Bernolet et al. 2007; Loebell and Bock 2003; Kidd et al. 2014). If the word order of the source text can be transferred to the translation, this can result in lower total reading times as has been shown by Jensen et al. due to a possible "automatic transfer of L1 syntax to all types of L2 processing" (Jensen et al. 2009, 333). However, there is also evidence that syntactic structures can be primed across languages if the word order in both languages is different. Desmet and Declercq (2006) tested a sentence completion task that showed syntactic priming effects for relative clause attachment from Dutch to English, even though word order restrictions such as verb final position of Dutch sentence is different from the word order in English.

Shin and Christianson (2009) investigated priming effects of functionally equivalent dative-constructions in Korean and English with the help of a sentence recall task. The English target sentence was presented via audio and was either a double object or prepositional object construction. These sentences were followed by a Korean prime either with a prepositional dative construction, post-positional dative construction or double object construction. In their analysis, they found evidence for an argument-order independent priming effect of post-positional dative constructions, primed by functional correspondences, as this construction is the functional equivalent of the canonical English prepositional dative. Similarly, Chen et al. (2013) observed priming effects of English passive structures on Chinese passive structures and vice versa, when participants were asked to describe a picture after being exposed to a passive or active priming sentence in the other language. Priming occurred despite different word orders. It is therefore possible that formal correspondences between languages are a strong but not a necessary factor for cross-linguistic syntactic priming.

Cross-linguistic semantic priming has been associated with a facilitation effect and structural cross-linguistic priming can thus be argued to also facilitate translation. Schoonbaert et al. (2007) found that cross-linguistic syntactic priming can be boosted if the verb is a translation equivalent in prime and target sentence. During translation, most words are of course translation equivalents and the relatively modest boost observed in priming studies can be assumed to be much stronger during translation.

Due to the nature of priming as a general psychological effect, it is to be expected that translators are affected by a structure in a source text to a similar degree. Translators that are thus primed by a syntactic structure, are likely to produce translations with the same syntactic structure in the target language. For the measure of syntactic variation, the logical consequence would be that lower entropy measures are related to priming since a single translation choice with a high translation probability can lower entropy drastically. Syntactic priming effects may depend on several characteristics of the input, for example, a cognate verb with the same argument frame.

10.3 Research Questions and Hypotheses

According to the theoretical framework presented above, we assume that the two languages are co-activated during translation. Furthermore, we hypothesise that priming works as a kind of default setting, i.e. shared syntactic nodes of the cognitive network are activated across the source and the target language providing a facilitation effect for the translator. Such facilitation effects should be reflected in lower cognitive effort, and hence in lower behavioural measures than in cases where translators tend not to use the same ST structure for the TT. For the latter case, we predict comparatively higher behavioural measures.

To measure priming effects in translation, we apply the concept of syntactic variance as measured by entropy. In particular, we address the following research questions:

(RQ1) • Can priming effects account for syntactic entropy in translation?
(RQ2) • What influences priming effects in translation?
(RQ3) • Does syntactic variation in translation (as measured by entropy) have an effect on cognitive effort?
(RQ4) • Do priming effects modulate the cognitive effort related to syntactic entropy?

These four research questions will be answered by testing the following hypotheses:

(H1) • Segments with low entropy values reflect priming effects and are highly correlated with lower behavioural measures as compared to segments with high entropy.
(H2) • We predict that priming probability has a negative effect on behavioural measures such that items which are highly likely to have the same syntactic structure as the source sentence receive less attention than those sentences which are highly unlikely to have the same syntactic structure as the source sentence. It is expected that priming probability interacts with syntactic entropy.

In the following, we will test the above hypotheses on the basis of datasets from two tasks—translation between one source language and three different target languages and monolingual copying of the same texts that were also used in the translation task. The copying task is similar to the translation task in that both tasks require source text reading and typing. However, copying does not involve transfer between two linguistic systems. In this sense, the copying data serves as a control condition: if the syntactic entropy effects we observe in the translation condition are also found in the copying task, it is likely that they represent monolingual source-language-related processes. If, however, syntactic entropy has no effect on behavioural measures during copying, it is likely that these effects are driven by task and target-language-related processes.

10.4 Translation Condition

10.4.1 Participants

The German data was produced by 24 translators (13 translation students, 11 professional translators), the Danish dataset contains translations from 24 translators (12 translation students, 12 professional translators). The Spanish data collection had the most translators with 32 translators but only five professionals (27 students, 5 professionals).

Sixteen subjects participated in the monolingual copying task. All of them had learned English at school and/or university for 4–18 years. Twelve of them were students currently enrolled in a translation programme, two have a degree in translation, and one was never engaged in translation studies. Due to calibration problems, one participant was excluded. Eye-tracking and keylogging data were thus collected and analysed for 15 participants. Twelve participants in the copying task were native speakers of German, one of Turkish, one of French, and one had German and Dutch as his/her first language.

Participants in the baseline condition had to fill out a questionnaire before the experiment. They were instructed to copy the English text and were informed that comprehension questions would follow the task. Three questions for comprehension followed the task. Keystrokes and gaze data were recorded with a Tobii T120 eye-tracker and processed with Translog II (Carl 2012).

10.4.2 Material

The translation data were extracted from the CRITT-TPR database (see Chap. 2): (SG12 for German, KTHJ08 for Danish, BML12 for Spanish) The datasets contain translations of the same six English source texts with the exception that the Danish Study contains only the first three source texts. The datasets contain eye tracking data from a Tobii T120 eyetracker, and keylogging information recorded with Translog (Jakobsen and Schou 1999) and the resulting data was processed with Translog II (Carl 2012) before analysis.

Table 10.2 Properties of the target texts of the translation and the copying condition respectively into the four target languages: Session (number of target texts), Fdur (in hours), Kdur (in hours), Tlen (number of target tokens)

Study	Session	TL	Task	Texts	Part	Fdur (in hours)	Kdur (in hours)	Tlen (in tokens)
TDA14	48	en	C	1–6	11	6.1	5.8	6792
KTHJ08	69	da	T	1–3	24	6.4	5.5	10,571
SG12	47	de	T	1–6	24	9.4	4.6	6632
BML12	63	es	T	1–6	32	8.2	5.8	8936
Total	227	4	2	6	91	30.1	21.7	32,931

Table 10.2 contains a detailed overview of the produced target texts: it indicates the translation (*Task)*, text copying (*C*), translation from-scratch (*T*) and participants (*Part*) involved, the number of translation sessions (i.e. target texts produced), as well as the duration and the total number of target language tokens for each translation mode. Translation (and copying) duration is measured in two different metrics:

- *Fdur*: total production time for all segments, excluding pauses >200 s.
- *Kdur*: total duration of coherent keyboard activity excluding keystroke pauses >5 s. (in the following, we will use refer to Kdur as coherent typing activity for ease of comprehension)

The BML12 study, for instance, contains 63 from-scratch translations which were produced by 32 translators (participants). Each participant had to edit, post-edit and to translate two texts in each mode, and texts were distributed in a randomized order. As shown in Table 10.2, the translated texts together amount to 32,931 target text words which were produced in the 227 translation sessions. Gaps of keystroke activity for more the 200 s (almost 2.3 min) are excluded, under the assumption that translation activities are interrupted in such instances. However, no such pauses were observed in these studies (Fdur is a standard measure in the database and other datasets do have pauses over 200 s).

Table 10.2 also contains information concerning the monolingual copying condition (TDA14) which will be used to contrast the results from the data acquired from the translation condition. A monolingual task that does not involve code-switching of any kind should not reflect entropy measures. Note that during the copying task 95 % of the text production time has been spent on coherent typing (*Kdur*).

10.5 Analysis

10.5.1 Annotation

A detailed description of the annotation used in this study, together with a discussion of possible alternative annotations is available in Chap. 12. In this section, we shortly summarize the main features.

The ST and the TT were parsed according to clause type, voice and type of argument structure. Clause type was annotated as either an independent or dependent clause. Simple sentences as well as main clauses were tagged as independent (I) while subclauses, were annotated as dependent (D). Voice was either annotated as passive (P) or active (A). The third dimension captured verb-argument structures. When the verb of the clause was subcategorized for a direct object or a complement, it was referred to as transitive (T). When it subcategorized for a prepositional object or no object it was labelled intransitive (I). Other argument structures considered were ditransitive structure (D) but also clauses with empty subjects or extraposed subjects (e.g. *Es comprensible que* . . . .[It is understandable that . . .]). These cases were tagged with (M) as in impersonal. A clause characterized as Transitive, Active and Independent thus receives the tag TAI. Segments with multiple clauses and thus multiple tags are merged to longer tags such as TAI_TAD representing a transitive active main clause with a transitive and active subclause. The probabilities of the different translations were computed on the basis of number of occurrences for each tag.

To assess the first and the second research questions, syntactic structures in the annotated translation data have been classified into two categories: PRIME and DIFFERENT. We consider as PRIME every TT segment that preserves the structure of the corresponding ST segment. The category DIFFERENT contains all segments which show a structural change in the TT segment as compared to its corresponding ST segment.

In addition to the original annotation, two new tags were assigned in a category which describes the relationship between the syntactic structures in corresponding source and target text segments. The tag PRIMED was attributed whenever ST and TT structure were identical. The tag DIFFERENT was used whenever different structures were used in the TT as compared to the corresponding ST segment.

The complete dataset was split up into language specific datasets. To identify cases of priming, the target text segments were annotated in the same way as the source text segments with the same annotation scheme as the source text. Source and target structures were compared and categorized as either a prime if they were the same or as different when their structures did not match (see Table 10.3). Title segments were excluded from the analysis due to unusual grammatical properties. This removed 10 % of the data so that 1156 observations remained for analysis.

To answer the research question on the relationship between entropy and priming effects and cognitive effort (RQ2), behavioural translation data from the three language pairs (English-Danish, English-German, English-Spanish) were annotated

Table 10.3 Example of a priming annotation

Source	Target	Count	Comparison	Priming probability
DAI	DAI	4	PRIMED	0.5
	DAI TAD	2	DIFFERENT	

for their syntactic structure and later jointly assessed in mixed linear models. A monolingual copying task served as a baseline. The baseline measures, in contrast to the translation condition, should not be affected by syntactic entropy since syntactic entropy is driven by the TL and not the SL. This control condition will confirm that syntactic entropy actually measures variation in translation and that it is not due to processes related to monolingual ST comprehension. Further, controls were integrated for the analyses of syntactic entropy by means of multivariate statistics controlling for potential confounding factors.

10.5.2 Statistical Analyses

For the analyses, the program R (R Development Core Team 2014) and the lme4 (Bates et al. 2014) and languageR (Baayen 2013) packages were used to perform linear mixed-effects models (LMMs). Since lme4 does not compute p-values, the R package lmerTest (Kuznetsova et al. 2014) was applied. It uses ANOVA for mixed-effects models using the Satterthwaite approximation to estimate degrees of freedom. The behavioural measures here are reported per source text segment as provided by the .sg files from the CRITT-TPR database.

10.5.3 Linear Regression Modelling

Behavioural measures that were chosen as dependent variable were coherent typing activity per word, total reading times for target text and source text per word as well as the average first fixation duration for each segment. Coherent Typing activity is defined as the duration of coherent keyboard activity excluding pauses that are longer than 5000 ms, measured for the production of each segment (see Chap. 2). Total reading time represents the sum of all fixations on a particular segment. The total reading times and coherent typing activity were normalized by dividing the segment measures by the number of tokens constituting the respective segment.

To assess whether priming is an effect that modulates the effect of syntactic entropy on behavioural measures, the ratio of primed to non-primed structures in each segment was assessed in addition to the prior measures of entropy. This ratio can be conceived of as priming probability p_{syn}. It is computed by dividing the number of primed syntactic structures i.e. translations of segments whose structures are the same as in the source text segment by the total number of translations of this segment (see Eq. 10.4).

$$p_{syn}\left(ST_{syn} == TT_{syn}\right) = \frac{primed}{\#translations} \tag{10.4}$$

A p_{syn} of one means that all translators chose the same structure and a p_{syn} of zero that no translator chose the same source text structure. p_{syn} enters the model as an interaction effect that is modelled as the product of syntactic entropy and p_{syn}.

The interaction effect of syntactic entropy and priming probability should be negatively correlated with measures of total reading time for example, because higher degrees of priming would facilitate processing and weaken the effect of variation.

10.5.3.1 Control Variables

In order to isolate the effect of entropy, a number of control variables were introduced:

Expertise is a strong determinant of translation behaviour. Experts are usually faster than non-experts. It is conceivable that experts may have developed selection strategies so that the effect from co-activation of translation equivalents is reduced, which would lower the effect of entropy on behavioural measures. Expertise is introduced to the model as a categorical variable: 1 represents professional translators, 0 students.

10.5.3.2 Clause Number Within a Segment

The more clauses a segment contains, the more complex it can be believed to be. It is thus possible that syntactic entropy does not capture variation but complexity since the annotation reflects the number of clauses. In production and in comprehension, the complexity of a segment can be thought to influence behavioural data either because reading speed increases because of the expectation of less important information in subclauses or due to difficulty in tracing coherence structure in complex sentences.

10.5.3.3 Word Length

Normalization by the number of words has the disadvantage that different word lengths cannot be accounted for. By chance, syntactic variation could be high in segments containing multiple long words and thus would be associated with higher reading times since longer words are more prone to multiple regressive eye movements and re-fixations. To control for this, average word length per segment has been computed for source text segments and the translated target text segment by dividing the total number of characters per segment by the number of words per segment.

10.5.3.4 Word Order Changes

Furthermore, the cognitive effort to align word orders between source and target language may be the reason for increased reading times. For this reason, the *Cross* feature has been introduced in the model given that the degree of reordering that was necessary to produce a translation may have an effect on behavioural measures (for an explanation of the *Cross* feature, see Chap. 2).

10.5.3.5 Inefficiency

Some segments may have been more prone to typographical errors and may have undergone major restructuring efforts. Therefore, inefficiency was introduced as a control variable. It is calculated by the number of characters produced during a translation divided by the final amount of characters in the final translation (see also Chap. 2).

10.5.3.6 Random Variables

The last two confounding factors that are controlled for are idiosyncratic differences of the different languages, different participants and items (i.e. the unique segments that were translated) accountable for some variation in the data. They are modelled as random effects, so that the model considers individual intercepts of each participant of each study, and each item.

10.5.3.7 Control over Confounding Variables for First Fixation Durations

Unfortunately for first fixation duration, no appropriate control for confounding factors apart from transformation demands, the random effects, and expertise exist in the dataset. Word length has a very low or even no impact on first fixation durations which is why it was not controlled for (Pollatsek et al. 2008). The contextual environment, i.e. predictability has a large effect on eye movements (e.g. Ehrlich and Rayner 1981). However, it is not possible to infer how constraining the context is from the data directly. The closest indicator that might capture context is priming probability: it is possible that high contextual constraints lead to a more condensed translation probability distribution (Prior et al. 2011, 107).

10.6 Data Trimming

For reading related measures the data was further trimmed so that average total reading times per word below 200 ms per word were excluded, as were segments that were headlines due to their unusual grammatical properties. Also, participants with an extremely bad data quality were excluded completely from reading time analyses when half of their normalized total reading duration fell below an average reading time of 200 ms. The behavioural measures provided by the three studies and three languages in the TPR database (BML12-Spanish, SG12-German and KTHJ08-Danish) were each logarithmically transformed to reduce skew so that the data assumed a shape more similar to a normal distribution. The behavioural measures for each study were then standardized by centering and scaling and assessed as a single dataset. Data points exceeding ±2.5 standard units were removed before analysis from all measures. 11.4 % of the data was removed from the coherent typing activity analysis (1121 observations left). 33.6 % of the data for total reading time of the source and average first fixation duration were removed (831 observations left). For the total reading time of the target text 34.2 % have been excluded (833 observations left).

10.7 RQ1: Syntactic Entropy and Priming

To test if priming effects can account for syntactic entropy measures, the segment groups termed *Different* and *Primed* were tested to find out if primed and non primed structures affect syntactic entropy differently. A Wilcoxon-Mann-Whitney significance test for categorical data was conducted. The test revealed significant differences in the distribution of primed and non-primed structures with respect to entropy. The difference between both structure types was highly significant for German (W = 16,250, p-value <0.001), Spanish (W = 24,476, p-value <0.001) and Danish (W = 36,572.5, p-value <0.001).

The groups i.e. primed structures and non-primed structures show a difference of almost one unit of entropy when assessing the median (Fig. 10.1). Priming effects by the source text are a very likely explanation for the very low entropy values of zero to one which indicates that priming can streamline translation and reduce syntactic variation.

10.7.1 RQ2: Restructuring and Priming

If priming effects do not result in adherence to the original structure, there may be a systematic reason. As has been indicated before, priming may be promoted by congruent word order for the same syntactic representation. In order to test this

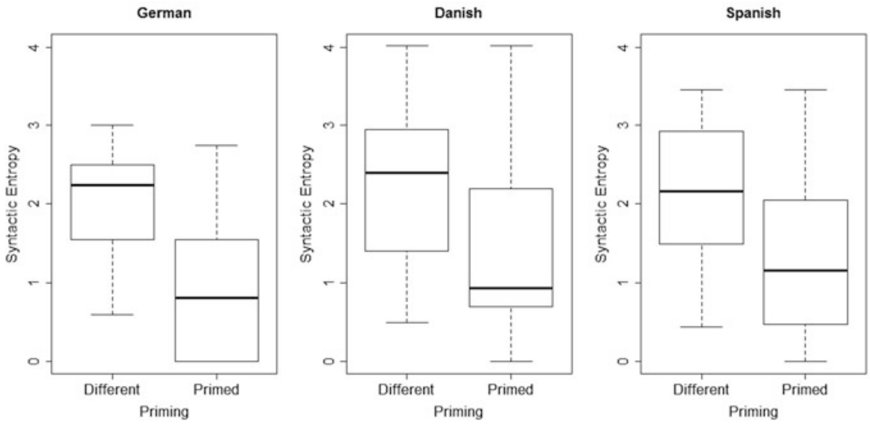

Fig. 10.1 Distribution of primed and non-primed structures in relation to entropy per language-pair

hypothesis, *CrossS* (see Chap. 2), i.e. the relative distortion from source text words to target text words was modelled as a predictor of priming probability with the help of a univariate linear regression. The model was significant with $F(1, 1154) = 40.83$, $p < 0.001$, $R2 = 0.03334$.

Figure 10.2 shows that structuring effort correlates negatively with priming probability. However, primed structures occur also in cases when the average *CrossS* value exceeds the value of 1, which is the literal translation default. Structural priming effects that occur despite congruence also corroborate studies by Chen et al. (2013), Desmet and Declercq (2006) and Shin and Christianson (2009), who provide evidence suggesting that word order similarity is not necessary for priming effects to occur. However, the results clearly indicate higher chances of priming for segments with lower to no restructuring effort. The lower entropy values for primed structures may indicate that increased restructuring effort is eventually a source of deviation from the syntactic representation of the source, since priming is inhibited.

10.8 RQ3: Syntactic Entropy and Behavioural Measures

10.8.1 Total Reading Time (Source)

This section provides the results of the multivariate linear regression analyses, beginning with source text specific eye-tracking measures, followed by production measures. Total reading time of the source was assessed to measure the impact of syntactic entropy (Table 10.4).

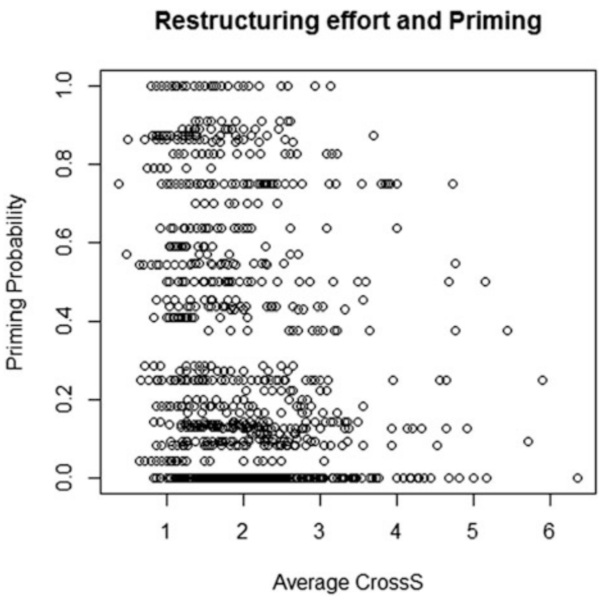

Fig. 10.2 Average cross predicting priming probability

Table 10.4 Linear mixed model (LMM) for the effect of Syntactic entropy on total reading time (source)

Formula	Total reading time (source) ~ syntactic entropy × priming probability + average word length + expertise + CrossS + (1|Participant) + (1|Unique_Segment-ID)			
Variable	β	Standard error	t-value	Significance level
Syntactic entropy	0.16	0.06	2.59	*
Priming probability	0.07	0.07	0.93	
CrossS	0.07	0.03	2.19	*
Number of clauses	0.07	0.03	1.99	*
Expertise	−0.31	0.18	−1.73	†
Average word length	0.17	0.07	2.50	*
Interaction effect	−0.04	0.05	−0.82	

The significance rates reflect participant and item variability
†$p < .1$, *$p < .05$

Syntactic Entropy turned out to be positively associated with total reading time of the source text (Fig. 10.3). Similarly, the restructuring effort (*CrossS*), clause complexity (number of clauses) and average word length of the segment displayed positive and significant slopes. The effect for expertise was marginally significant such that professional translators read the source faster than non-professional translators.

The control variables displayed no unexpected behaviour, so that the model seems to measure these dimensions quite well. The fact that no significant

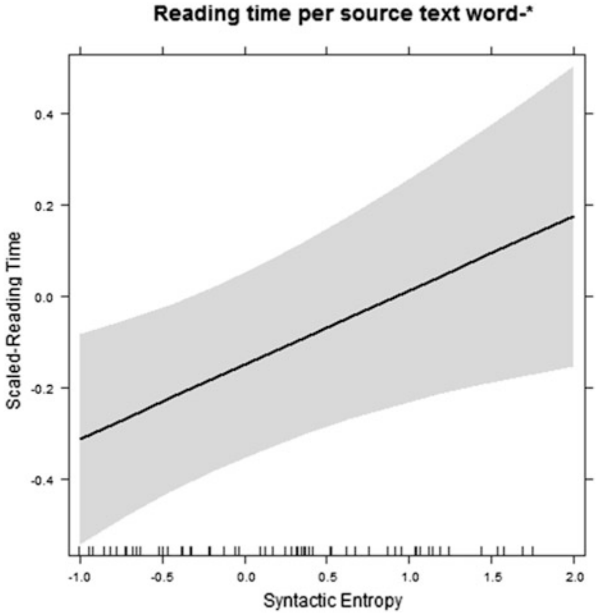

Fig. 10.3 The effect of syntactic entropy on total reading time (source)

interaction effect could be observed for Syntactic Entropy and priming probability nor for priming probability alone contradicts the hypothesis that the effect of entropy on behavioural measures is further modulated by priming effects.

10.8.2 First Fixation Duration

The model for the average first fixation duration of source text words, consisted only of Syntactic Entropy and Priming probability. In this model, entropy displayed a small but marginally significant positive effect on average first fixation duration (Table 10.5).

Further research is warranted to assess the effect of entropy on measures of first fixation duration with more control over confounding factors. The effect of syntactic entropy on a measure of first fixation duration for words may suggest that phenomena of syntactic choice are influencing lexical recognition processes from very early on. A possible reason for higher first fixation durations may be that each of the already activated syntactic choices may compete for integration with the new input, which would of course presuppose that several possible alternative structures are entertained in parallel, rather than serially. However, given the fact that the effect is very weak and given that we only took average first fixation durations into consideration, more research is needed to draw more resilient conclusions.

Table 10.5 LMM for the effect of syntactic entropy on first fixation duration (source)

Formula	Average first fixation duration ~ syntactic entropy × priming probability + (1|Participant) + (1|Unique_Segment-ID)			
Variable	β	Standard error	t-value	Significance level
Syntactic entropy	0.08	0.05	1.77	†
Priming probability	0.02	0.06	0.37	
Interaction effect	−0.04	0.04	−0.96	

The significance rates reflect participant and item variability
†$p < .1$

Table 10.6 LMM for the effect of syntactic entropy on coherent typing activity (target)

Formula	Coherent typing activity (Target) ~ syntactic entropy × priming probability + average word length (T) + clause complexity + expertise + CrossS + (1|Participant) + (1|Unique_Segment-ID)			
Variable	β	Standard error	t-value	Significance level
Syntactic entropy	0.13	0.04	3.22	**
Priming probability	0.05	0.04	1.36	
Typing inefficiency	0.52	0.02	27.56	***
CrossS	0.01	0.02	0.22	
Number of clauses	0.00	0.02	−0.28	
Average word length	0.41	0.03	14.36	***
Expertise	−0.29	0.15	−1.96	†
Interaction effect	−0.03	0.05	−0.49	

The significance rates reflect participant and item variability
†$p < .1$, **$p < .01$, ***$p < .001$

10.8.3 Coherent Typing Activity

During production, syntactic entropy showed a highly significant and positive association with coherent typing activity. Typing inefficiency and average word length were significant predictors of coherent typing activity. The difference between professional translators and translation trainees was marginally significant and suggests that professional translators tend to be faster writers than non-professionals.

The results obtained here indicate that translation choice in terms of syntactic structure not only slows down reading processes of the source and target text (see below), but also coherent typing activity. Slower typing activity may be caused by higher cognitive load due to selection pressure but also due to revisions. The strong influence of typing inefficiency may be an indication for this (Table 10.6; Fig. 10.4).

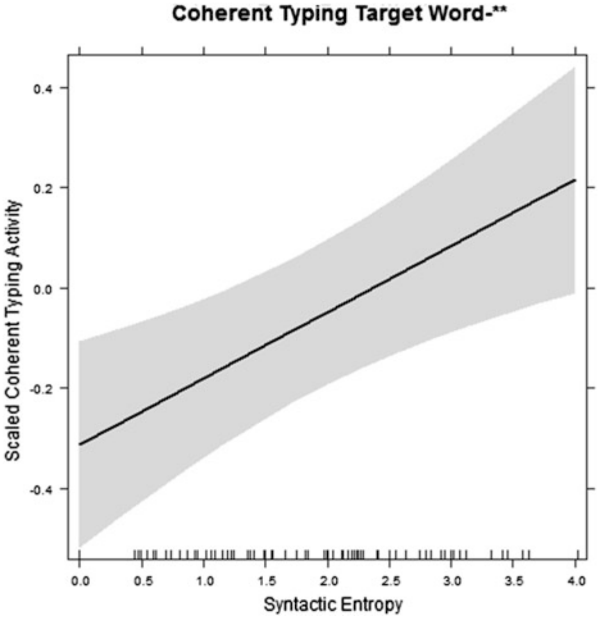

Fig. 10.4 The effect of syntactic entropy on coherent typing activity (target)

10.8.4 Total Reading Time (Target)

For the total reading times of the target text syntactic entropy was again associated with a marginally significant increase of reading duration. Compared with total reading time of the source text, the effect of syntactic entropy on total reading time of the target is slightly less pronounced. This is plausible since in the revision phase of a translation task, gaze accumulates on different stretches of text for detection and correction of typos and mistakes. The effect of syntactic entropy is thus more measurable in the drafting phase of translations. Typing inefficiency was the strongest significant predictor of reading time in the model, followed by average word length. The number of clauses showed a slight but significant decrease in total reading time. Skipping less important stretches of text, e.g. dependent clauses during revision may be a likely explanation (Table 10.7).

Table 10.7 LMM for the effect of syntactic entropy on total reading time (target)

Formula	Total reading time (target) ~ syntactic entropy × priming probability + average word length (T) + clause complexity + inefficiency + expertise + CrossS + (1|Participant) + (1|Unique_Segment-ID)			
Variable	β	Standard error	t-value	Significance level
Syntactic entropy	0.11	0.06	1.83	†
Priming probability	0.00	0.07	−0.05	
CrossS	−0.01	0.03	−0.17	
Expertise	−0.02	0.14	−0.12	
Typing inefficiency	0.24	0.03	8.73	***
Number of clauses	−0.07	0.03	−2.61	**
Average word length	0.23	0.04	5.84	***
Interaction effect	−0.03	0.05	−0.49	

The significance rates reflect participant and item variability
†$p < .1$, **$p < .01$, ***$p < .001$

10.9 Analysis of the Control Group

In order to verify that syntactic entropy is indeed driven by target-language-related and task specific aspects and not by SL processes, the copying data was tested against the entropy values of each language:

behavioural Measures of the Copying condition ~ Syntactic Entropy (German) …
behavioural Measures of the Copying condition ~ Syntactic Entropy (Danish) …
behavioural Measures of the Copying condition ~ Syntactic Entropy (Spanish) …

Cleaning of the copying data was conducted in the same fashion as the translation condition. For coherent typing activity, 14 % of the data was excluded (528 observations left), for total reading time on the source 19 % was excluded (500 observations left), for first fixation durations 19 % of the data was discarded (496 observations left) and total reading time on the target text 42 % of the data had to be excluded (375 observations left).

The same random effects as before entered the equation. The results for the copying condition were controlled for average word length per segment, typing inefficiency and number of clauses per segment. Translation expertise, priming probability, and restructuring are unlikely to play a role in a copying task, which is why they have not been included to avoid unwarranted over-fitting of the model.

10.9.1 Total Reading Time of the Source

The model for total reading time of the source displayed, as expected, only a significant effect for average word length, such that average word length was positively associated with longer average total reading times of the source. Syntactic Entropy was not significant (Table 10.8).

10.9.2 First Fixation Duration (Copying)

Maybe not surprisingly, none of the syntactic entropy values from either of the languages had an effect on first fixation durations during copying (Table 10.9).

Table 10.8 LMMs total reading time (source) (copying)

Formula	Total reading time (source) ~ syntactic entropy(language) + average word length + number of clauses + (1|Participant) + (1|Unique_Segment-ID)				
	Variable	β	Standard error	t-value	Significance level
Spanish	Syntactic entropy	0.02	0.09	0.23	
	Number of clauses	−0.03	0.04	−0.91	
	Average word length	0.34	0.12	2.93	**
German	Syntactic entropy	0.07	0.10	0.76	
	Number of clauses	−0.04	0.04	−1.04	
	Average word length	0.32	0.12	2.64	*
Danish	Syntactic entropy	0.07	0.10	0.63	
	Number of clauses	−0.03	0.05	−0.70	
	Average word length	0.44	0.19	2.37	*

The significance rates reflect participant and item variability
*$p < .05$, **$p < .01$

Table 10.9 LMMs for first fixation duration (source) (copying)

Formula	First fixation duration ~ syntactic entropy + (1|Participant) + (1|Unique_Segment-ID)				
	Variable	β	Standard error	t-value	Significance level
Spanish	Syntactic entropy	−0.02	0.05	−0.46	
German	Syntactic entropy	0.05	0.05	0.98	
Danish	Syntactic entropy	−0.01	0.06	−0.25	

Table 10.10 LMMs for coherent typing activity (copying)

Formula	Coherent typing activity ~ syntactic entropy + average word length (T) + number of clauses + inefficiency + (1|Participant) + (1|Unique_Segment-ID)				
	Variable	β	Standard error	t-value	Significance level
Spanish	Syntactic entropy	0.03	0.05	0.61	
	Number of clauses	−0.01	0.02	−0.69	
	Typing inefficiency	7.08	0.44	16.17	***
	Average word length	0.57	0.07	8.10	***
German	Syntactic entropy	0.05	0.06	0.78	
	Number of clauses	−0.01	0.02	−0.77	
	Typing inefficiency	7.08	0.44	16.16	***
	Average word length	0.56	0.07	7.67	***
Danish	Syntactic entropy	0.08	0.06	1.37	
	Number of clauses	−0.01	0.03	−0.32	
	Typing inefficiency	7.91	0.67	11.73	***
	Average word length	0.47	0.10	4.78	***

The significance rates reflect participant and item variability
***$p < .001$

10.9.3 Coherent Typing Activity

As expected, in the control condition, no significant effect for Syntactic Entropy nor clause length could be observed. Typing inefficiency and average word length were highly significant (Table 10.10).

10.9.4 Total Reading Time (Target)

No effect of syntactic entropy on total reading time of the target segment could be found for Danish, Spanish or German entropy values. Only Average word length and typing inefficiency were significant contributors to total reading time in Spanish and German (Table 10.11).

No significant effects of syntactic entropy on any of the behavioural measures during copying were observed. This suggests that syntactic entropy measures an effect that is driven by the target language, i.e. it supports the view that, during translation, both languages are co-activated. It further suggests that translators entertain more than one possible target structure.

Table 10.11 LMMs for total reading time (target) (copying)

Formula	Total reading time (target) ~ syntactic entropy + average word length (T) + number of clauses + inefficiency + (1|Participant) + (1|Unique_Segment-ID)				
	Variable	β	Standard error	t-value	Significance level
Spanish	Syntactic entropy	−0.13	0.09	−1.49	
	Number of clauses	0.00	0.03	−0.14	
	Average word length	0.35	0.12	2.84	**
	Typing inefficiency	2.94	0.73	4.04	***
German	Syntactic entropy	−0.05	0.11	−0.43	
	Number of clauses	−0.01	0.03	−0.34	
	Average word length	0.37	0.13	2.88	**
	Typing inefficiency	2.91	0.73	4.01	***
Danish	Syntactic entropy	0.05	0.14	0.34	
	Number of clauses	−0.02	0.06	−0.36	
	Average word length	0.15	0.24	0.63	
	Typing inefficiency	2.28	1.25	1.82	†

The significance rates reflect participant and item variability
†$p < .1$, **$p < .01$, ***$p < .001$

10.10 General Discussion

Syntactic entropy was a significant predictor of increased total reading time of the source text segments and a marginally significant predictor for average first fixation durations on the reception side of the translation. On the production side total reading time of the target text and coherent typing behaviour were associated with performance decreases (marginally significant in the case of total reading time of the target and significant in the case of coherent typing). Higher behavioural measures may thus be taken as an indication of competition between multiple syntactic translation equivalents and the selection pressure generated from a set of co-activated syntactic realizations increasing cognitive load. This observation corroborates accounts that claim co-activation of linguistic systems during translation (e.g. Macizo and Bajo 2006; Ruiz et al. 2008). Results showed that these effects are driven by the target language and the translation task, since syntactic entropy was not a significant predictor of behavioural measures when participants copied the texts.

Although the syntactic annotation of the data was very shallow, it was possible to measure variation and priming effects. They manifested in structural repetition of syntax found in the source text segment and occurred mainly in the vicinity of low syntactic variation, indicating that many translators were structurally primed by the source. Low syntactic variation is thus likely a result of syntactic priming, influencing translators to reproduce the syntactic structure they read in the source text.

It was surprising that the interaction between priming probability and syntactic entropy was not significant. A deeper level of analysis might lead to different results when, for example, levels of embedding and a finer analysis of the clause type are assessed (see Chap. 12). But since the argument structure is captured in the first dimension of the annotation scheme and subject variation is accounted for to some degree by voice in the second dimension, priming effects due to functional correspondences are probably reliable.

Furthermore, priming effects were hypothesized to be strongly modulated by word order and less so by mere functional correspondence. The results for the linear regression with *CrossS* confirmed the hypothesis, that congruent word order is a strong but not a necessary condition for syntactic priming, since even higher priming probabilities were possible when the literal translation threshold of a *CrossS* value of 1 was exceeded.

While the hypothesis that priming effects are a major factor for decreased syntactic variation could be confirmed, no significant facilitation effect could be observed for the interaction effect of syntactic entropy and priming probability. This may indicate that priming did not have the expected degree of influence on syntactic variation. Other processes that regulate variation may have been underestimated. For example, when a primed structure is incompatible with target norms, translators may choose a different structure in order to produce a target sentence that is compatible with target norms. If many translaters choose the same structure, the resulting entropy value would by lowered in a similar fashion to a priming effect, but it may not display a facilitation effect. This could be why the interaction effect of priming probability and syntactic entropy was not behaving as expected. Another possible explanation for this observation is that options that are primes are monitored carefully to avoid such target language norm violations. This would in turn lead to longer reading times. Decreased translation performance for non-norm conforming structures has been noted by Vandepitte and Hartsuiker (2011). In their study Dutch translators displayed difficulties when translating English SVO structures containing inanimate subjects to Dutch when adhering to this structure. Inanimate subjects tend to not take subject position in Dutch. A monitoring effect may thus cancel the effect of priming in text production.

10.11 Conclusion

The results presented here corroborate the view of shared linguistic representational structures. This chapter shows that the scope of shared linguistic representational structures is not restricted to lexical items but extends to syntax since syntactic co-activation of multiple possible structures is reflected in longer behavioural measures similarly to words with multiple translation alternatives. The results presented here expand and lend further support to the literal translation hypothesis.

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