

# MT syntactic priming effects on L2 English speakers

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## Abstract

In this paper, we tested 20 Brazilian Portuguese speakers at intermediate and advanced English proficiency levels to investigate the influence of Google Translate's MT system on the mental processing of English as a second language. To this end, we employed a syntactic priming experimental paradigm using a pretest-priming design which allowed us to compare participants' linguistic behaviour before and after a translation task using Google Translate. Results show that, after performing a translation task with Google Translate, participants more frequently described images in English using the syntactic alternative previously seen in the output of Google Translate, compared to the translation task with no prior influence of the MT output. Results also show that this syntactic priming effect is modulated by English proficiency levels.

## 1 Introduction

Machine Translation systems (MT), especially Google Translate, have become popular in the last decades (Clifford et al., 2013). The popularity of these systems has grown not only due to technical improvements, but also due to the facilitation of users' access through the proliferation of mobile applications containing a number of functions that allow users to translate from texts, from speech or from a text image (Gupta and Dhawan, 2019; Chinnery, 2008). The rapid development of

MT technologies is the result of massive research investment in the field over the past decades focusing on language resources, new methods and techniques with the aim of improving the quality of the MT output. Consequently, the progress made in MT technology has changed the way people are engaging with these systems (Gaspari and Hutchins, 2007).

In the past, MT systems were used mainly for gisting purposes, but nowadays they are also being used as a tool supporting writing skills, grammar skills and language production in a second language (L2) (Niño, 2006; Garcia and Pena, 2011). However, research in the MT field focusing on end-users is limited so that, currently, little we know about what the users' interaction with an MT system could bring to the mental processing of a second language. In this paper, we aim at investigating the role MT systems play, especially, the role that the popular MT system Google Translate plays on the processing of English as a second language. Specifically, we investigate the influence of Google Translate on the processing of English as L2 by testing whether the MT output can influence the way MT users process English syntax. We address the following research questions:

1. Is the use of MT capable of affecting the way a second language is being processed by users when speaking in a second language?
2. Can MT systems facilitate the access and processing of syntactic structures that pose a challenge to L2 English speakers?

To the best of our knowledge, these questions remain unaddressed in the MT literature and deserve further scrutiny.

To accomplish this paper's goal, we carried out a syntactic priming study, an experimental paradigm

commonly used by researchers in the field of psycholinguistics, as a way to understand aspects of the representation and processing of language syntax (Branigan et al., 2000). The syntactic priming approach enabled us to understand the influence of the MT in participants' linguistic behaviour after exposition to the MT output. Due to differences in syntactic structures, we focused in particular on Portuguese-English (PT-EN) translation.

Before presenting our methodology in detail, we highlight the progress that has been made in previous research focusing on syntactic processing adopting the syntactic priming methodological paradigm.

## 2 Related work

The syntactic priming effect, known as *syntactic alignment* or *structural alignment*, occurs when people, in a communicative context, repeat the same syntactic structure previously seen, heard or read (Bock, 1986).

The first priming effect was reported by Lev-elt and Kelter (1982) who observed a repetition in grammatical structure in a question-and-answer telephone experiment in which merchants were asked either (a) "At what time does your store close?" or (b) "What time does your store close?". The researchers observed that the merchants were much more likely to respond to (a) with a sentence also starting with a preposition, such as "At 6 o'clock", and to questions such as (b) with a noun-phrase, such as "6 o'clock". Bock (1986) was the first to implement a laboratory study to investigate this repetition effect and developed an experimental paradigm to understand its characteristics in a controlled and naturalistic manner at the syntactic level. The experiment consisted of reading a sentence and asking participants to repeat out loud the same sentence. Listening and repeating the sentence was considered the "prime phase" of the experiment as the experimenter could control participants' exposure to different syntactic structures. Following the "prime phase", participants were requested to describe an image so that the researcher could observe if participants would use the same structure they had just produced in the prime phase in the subsequent utterance. Bock (1986) noticed that in their subsequent utterance participants tended to use the same syntactic structure previously heard and repeated. After this seminal study, a number of studies have shown syntac-

tic priming evidence between human interlocutors in L1 (Bock, 1986; Bock and Kroch, 1989; Bock et al., 1992; Hartsuiker and Kolk, 1998; Bock and Griffin, 2000) and L2 (McDonough, 2006; Shin and Christianson, 2012) interactions. These studies have also revealed that less frequent syntactic structures prime more than more frequent structures (Ferreira and Bock, 2006). For example, passive structures which are less frequently used by English and Dutch speakers prime more than active structures that are more frequently used (Bock, 1986). Some researchers call this effect as the "inverse preference effect" and they claim that the most uncommon structures drive the priming effect (Heyselaar et al., 2017a; Heyselaar et al., 2017b).

This repetition effect (Heyselaar et al., 2017a) has also been shown between humans and computers (Branigan et al., 2003). Cowan et al. (2015) found syntactic alignment in human-computer speech-based interactions for both dative structures (e.g. *give the waitress an apple* vs. *give the apple to the waitress*) and noun phrase structures (e.g. *a purple circle* vs. *a circle that is purple*) evidencing that a computer system can also influence a speaker's grammatical choices in speech-based interactions.

Virtual reality studies have also demonstrated syntactic alignment between humans and computer avatars. Heyselaar et al. (2017b) observed a priming effect for passives and actives, although the priming effect was stronger for passives than for actives. Suzuki and Katagiri (2007) have also found prosodic alignment between humans and computers. In their experiment, people exhibited alignment of loudness and response latency in their speech in response to computer-generated speech. Oviatt et al. (2004) found that children talking to computer partners spontaneously adapt several basic acoustic and prosodic features of their speech by 10–50%, with the largest adaptations involving utterance pause structure and amplitude. In addition, both naturalistic (Stoyanchev and Stent, 2009) and laboratory research (Branigan et al., 2003) investigating speech-based interactions between humans and computers have also shown that people tend to align syntactically with computers.

From the findings presented above, it is possible to conclude that, in an interactive context, speakers tend to syntactically align with their interlocutors both in first and second languages as well as with computer partners. Importantly, these studies show

that syntactic priming plays a central role in successful communication since it can promote mutual understanding through the semantic and structural representations shared by interlocutors (Pickering and Garrod, 2004).

In this paper, we report the preliminary results of a study that investigates whether human participants, specifically L2 speakers of English, syntactically align with MT output after performing a translation task. In other words, we investigate whether users are primed by the MT output when speaking in a second language. We expect that if, after performing a translation task using an MT system, the syntactic structure from the translation task is observed in the speakers' subsequent utterance, then MT output can influence the syntactic processing of English as a second language.

Despite a number of studies demonstrating syntactic priming between humans and computers, to the best of our knowledge, this is the first time syntactic alignment between an MT system and a human partner has been investigated.

The present study also expands previous syntactic priming studies. For the first time syntactic priming is tested from text (comprehension) to speech (production) by means of a cross-linguistic task (translation task) using a computer tool. Based on previous findings, we hypothesize that when translating a text using an MT, the user's syntactic choices when producing speech in a second language will mirror the syntax of the MT output.

To test these hypotheses, we carried out a behavioural syntactic priming study using an experimental paradigm commonly used in syntactic priming studies in the field of psycholinguistics (Pickering and Ferreira, 2008). Based on Shin and Christianson (2012), we adopted a pretest-priming design as it enabled us to study the influence of the MT on participants' performance in a picture description priming task as compared to the pretest baseline. In addition to the two general research questions presented above, by adopting the syntactic priming methodological paradigm we aim at answering the following specific research question:

- Would Portuguese speakers use a more difficult syntactic structure to process in English in their subsequent speech after exposure to this structure through Google Translate's output?

In the following sections, we describe the methodology employed in detail.

## 3 Method

### 3.1 Participants

We recruited 20 native speakers of Brazilian Portuguese (14 women) to take part in the study, through posts on social networks and the distribution of advertisements in English schools in Dublin, Ireland. Participants received a €10 voucher in return for taking part. We excluded one participant from the dataset as the person reported difficulties in completing the tests, leaving 19 participants in the sample. Prior to the experimental sessions, all participants gave written informed consent to participate in the experiments and read the plain language statement.

All participants were living in Dublin, Ireland, at the time of data collection and reported having received formal instruction in English. The average age of the sample was 33.7 years ( $sd=5.6$ ) with all participants being either at intermediate or advanced English proficiency levels according to the online Cambridge General English test<sup>1</sup> (25 question test; Mean test score= 13.8 ( $sd=4,5$ )).

### 3.2 Dependent Variable- Noun Phrase Syntax

Our research focuses on the participant's production of an English noun phrase with a relation of possession between nouns (e.g. *the cutlery handles are colourful* or *the handles of the cutlery are colourful*). We focused on this structure as this type of noun phrase varies across the participants' native and non-native language.

In Portuguese, only one syntactic alternative exists to represent a relation of possession between nouns. The relation is always encoded in the preposition *do* (de + o) or *da* (de + a) (e.g. *a mesa do escritório está cheia* or *a porta da casa está fechada*). Yet in English this relation can be represented using either a prepositional noun phrase (PNP), which follows the same word order as in Portuguese (e.g. *the table of the office is full*), or a non-prepositional noun phrase (NP) (e.g. *the office table is full*), which differs from Portuguese in word order. This allows us to identify whether syntactic priming by the MT output can lead Portuguese participants to produce NP structures more frequently in English which is an unfamiliar, and

<sup>1</sup><https://www.cambridgeenglish.org/test-your-english/general-english/>

more complex structure for these L2 speakers to process.

### 3.3 Experiment Task

Participants were asked to take part in an experimental game involving two stages; a pretest and a priming test phase. In the pretest phase, participants were asked to translate sentences depicting images from Portuguese into English using words provided below each image. In the priming test phase, participants had to describe, after a translation task using Google translate, the images displayed on a computer screen using speech. This is similar to the design used in previous second language syntactic priming studies (Shin and Christianson, 2012).

To construct the stimuli trials used in the pretest and priming test, we used a total of 104 images all of them retrieved from an online image repository<sup>2</sup>. The stimuli were presented on a computer screen using *Psychopy* software<sup>3</sup>. During the pretest and priming test, all verbal responses were recorded on Quick Player voice recorder.

### 3.4 Google Translate output

Prior to the construction of the experiment materials, we tested how Google would translate the Portuguese sentences created for the priming phase of the experiment. We observed that all sentences in Portuguese were translated from Portuguese into English using a NP structure far more frequently than a PNP structure. All the 40 sentences used in the priming phase were Google translated with a NP structure which is, as already mentioned, a more challenging syntactic alternative to Portuguese speakers. Based on this observation, we hypothesize that participants will produce more NP constructions after being exposed to the MT output than PNP constructions, but they will produce more PNP constructions in the pretest because the pretest does not involve participants' exposure to MT output. Observing the use of NP structure after being exposed to the output would suggest that the MT system would be facilitating the access to a syntactic alternative that is more complex to process for Portuguese speakers.

<sup>2</sup><https://elements.envato.com/>

<sup>3</sup><https://www.psychopy.org/>

### 3.4.1 Pretest stage

#### 3.4.2 Materials

The pretest consisted of 26 trials which were presented in a random order. The game was self-paced, i.e., all trials were presented until the participants responded. Participants were allowed to reformulate their answer once in case they noticed a mistake.

From the 26 trials, 20 trials consisted of images depicting a scene that was described in a sentence in Portuguese composed of a noun phrase subject, an auxiliary verb and a complement (e.g. *Os armários da cozinha estão organizados* – “kitchen cabinets are tidy”). The 6 remaining trials were filler trials (30% of the priming trials) consisting of sentences composed of a subject (definite article + noun), an auxiliary verb and complement (e.g. *A porta está trancada* – “the door is locked”) as well as images depicting those sentences. These 20 pretest trials provided a baseline because they enabled us to test the frequency at which participants produced the different syntactic alternatives in English when translating without any influence of an MT system.

#### 3.4.3 Procedure - Pretest stage

Participants were instructed to orally translate the sentences on the computer screen from the Portuguese into English. All sentences depicting the images involved a relation of possession so that they all could be translated into English using either a PNP construction or a NP construction. Below each image, we provided the words in Portuguese and their equivalents in English so that the use of participants' preferable syntactic alternative to translate the sentences was not hindered by any lexical retrieval issues. Figure 1, below, shows examples of pretest trials.

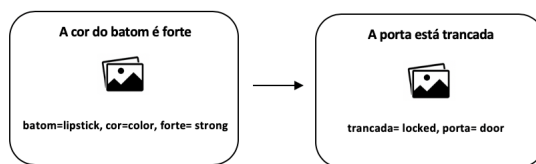
#### 3.4.4 Priming stage

#### 3.4.5 Materials

The priming test consisted of 26 trials, comprised of prime-target (prime condition) and filler prime-target (filler condition) pairs. Like the pretest stage, the priming stage was also self-paced. The items were presented in a random order one after another in one go, immediately after completing the pretest.

Each trial included two items preceding a target description item. There were 20 trials where two items acted as primes for the English MT translated structure (prime-target trials) and 6 filler trials

**Figure 1:** Examples of trials presented in the baseline pretest. Participants translated the sentences depicting images out loud using the words provided below each image.



(30% of the 20 prime trials) where the two items primed an unrelated syntactic structure (i.e. intransitive structure). The prime trials were created using 40 sentences in Portuguese with a relation of possession and pictures depicting those sentences (e.g. *A mesa do escritório está cheia*). Targets were constructed using 20 images presented to participants with three words appearing on top of each one (e.g. *room, rug, dirty*). In the filler condition, the prime sentences in Portuguese and pictures depicting those sentences were constructed using 12 intransitive sentences (e.g. *O homem está trabalhando*) and 6 target pictures presented to participants for description using one intransitive verb (e.g. *praying, smiling, studying*) appearing on top of each image. Prime items and target items were different as no words were repeated between them. This procedure allowed us to isolate the syntactic priming effect from syntactic repetition effect boosted by word repetition (Pickering and Branigan, 1998).

### 3.4.6 Procedure - Priming stage

Participants were instructed to Google translate into English the two prime sentences in Portuguese depicting the image using the Google Translate application on their own mobile device and repeat the MT output out loud, thus triggering the syntactic priming effect (Konopka and Bock, 2009). Immediately after this task, in the target images, participants were instructed to construct and speak out loud a sentence in English without the help of Google Translate using the three words (prime condition) or the intransitive verb (filler condition) presented right above the images. They were also instructed to keep the sentence as simple as possible by avoiding adding words that were not on the computer screen or using prepositions of location (such as *in, on, at*) to construct the sentences. This procedure allowed us to test whether participants would describe the image mirroring the NP syntactic alternative of the Google Translate output (which differs from the Portuguese word order) or

whether they would describe the image using the PNP syntactic alternative which is easier to process.

Two prime-target trials in the two conditions that did not appear in the main experiment were introduced for participants' training before the start of the priming test.

Below, Figure 2 shows one example of trial of the priming test.

## 4 Analysis and coding

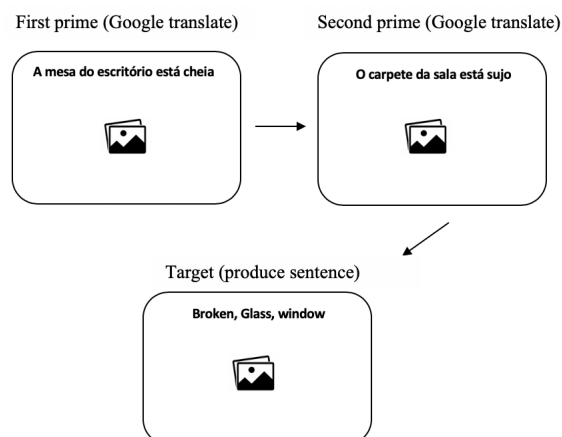
Verbal responses were transcribed and manually coded for the syntactic structure used to create the factorial dependent variable *Prime*. We coded a sentence as "1" if participants produced NP constructions mirroring Google Translate syntactic alternative and as "0" if they produced PNP constructions or any other syntactic construction such as *the office's table is full* or *the window in the house is broken* that have not appeared in the output of the MT.

After coding participants' responses (20 pretest and 20 priming test), we obtained a dataset containing 760 data points ( $19 \times 40 = 760$ ). The dataset was modelled using mixed-effects logit model and the `glmer` function of the `lme4` package version 1.1.-4; (Bates et al., 2011) in R (R Core Development Team, 2011).

The mixed-effects logit model is a linear regression model used to handle the repeated measures nature of a dataset whose dependent variable is binomial. As fixed effects, we included the English proficiency test score (continuous) to investigate the influence of this variable on participants' responses and a factorial predictor *Test* with two levels: baseline pretest and priming test.

Following Barr et al. (2013), we used a maximal random-effects structure. We began with a maximal model and then performed a step-wise reduction procedure to find the simplest model that did not differ significantly from the full model in terms of variance explained. The numeric predictor (En-

**Figure 2:** Example of trial presented in the priming test. Participants Google translated the sentences of the first and second primes in the two conditions and, in the target item, were instructed to describe the images out loud using the words provided above each image.



glish test score) was centered and the factorial predictor (Test) was dummy coded (all means compared to a reference group). P-values reported here were obtained by means of ANOVA type 3, test Chisquare. In order to make sure that the inclusion of the random slopes and random intercepts are justified we used Likelihood ratio tests which allowed us to compare the models (Baayen et al., 2008). Based on this process, the final model included by participant random slopes for Test and by-item random intercepts as random effects.

## 5 Results

Figure 3 below shows the influence of Language Proficiency on priming effect. Participants at higher English proficiency levels tended to produce more NP constructions during the priming test phase than participants at lower English proficiency levels.

Table 1 shows average percentages of structures produced by participants in the pretest and priming test. In the pretest, participants produced on average 38.42% of PNP constructions, 33.42% of NP constructions and 26.16% of other constructions such as *The window in my room is wide* or *The office's table is full*. In the prime test, participants produced on average 10.5% of PNP constructions, 55% of NP constructions and 34% of other constructions. Thus, as predicted, in the pretest (i.e. the test without any prior influence of syntactic constructions), participants produced on average more PNP constructions. However, after being primed by the NP constructions produced by the Google Translate output, the average percentage of PNP

constructions decreased 27.92% while the average percentage of NP constructions increased 21.58%.

**Table 1:** Average percentages of NP, PNP and other response choices

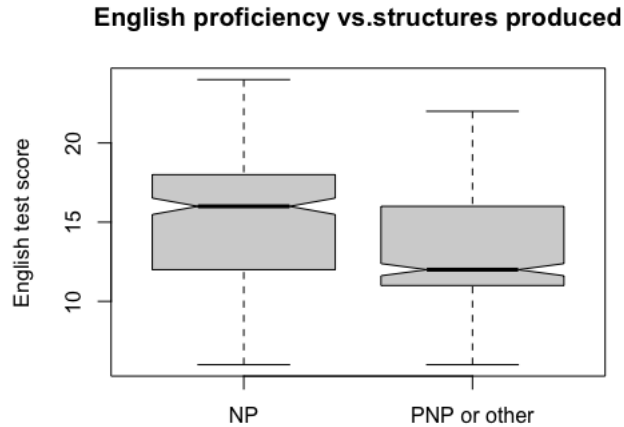
Structure	Pretest	Priming
PNP	38,42%	10,50%
NP	33,42%	55%
Other	28,16%	34%

Table 2 summarizes the fixed and random effects of the model fit for this dataset.

In the priming test condition, more NP constructions were produced compared to the baseline ( $p < .001$ ). This indicates that, after performing a translation task using Google Translate, participants tended to use significantly more NP constructions, thus mirroring the syntactic structure previously seen in the Google Translate output when speaking in English.

Results also show a significant effect of language proficiency ( $p < .001$ ), demonstrating a difference between participants' responses at higher and lower levels of English proficiency as well as a significant interaction ( $p < .05$ ) between factors *Test* (Baseline vs. Priming Test) and *EnglScore* (participants' English proficiency test score) suggesting that participants at higher levels of English proficiency produced more NP constructions during the priming test than participants at lower levels of English proficiency.

**Figure 3:** Boxplots showing the influence of the language proficiency on the priming test



**Table 2:** Summary of the best mixed effects logit model for participants' structure choices. Estimate (Est), Variance (Var), Standard Deviation (SD), Correlation (Corr), Standard Error (SE), Random effects (RE) and Fixed effects (FE). Final model formula:  $\text{Prime} \sim \text{EnglishTestScore} * \text{Test} + (1 + \text{Test} | \text{Subject}) + (1 | \text{items})$

RE				
	Name	Var	SD	Corr
items	intercept	0,02529	0,1590	
subject	intercept	1,49830	1,2240	
	PrimingTest	0,55407	0,7444	-0,57
FE				
	Est	SE	Z-value	P-value
(Intercept)	0,9207	0,3226	2,853	0,00432
PrimingTest	-1,4193	0,3520	-4,032	5,52e-05
EnglScore	-1,2223	0,2582	-4,733	2,21e-06
PrimingTest: EnglScore	0,6045	0,3053	1,980	0,04769

Google Translate output, participants used noun phrase structures without a preposition, as a direct result of exposure to sentences with these structures in English. This structure represents the syntactic alternative more likely to elicit processing difficulties due to word ordering differences between Portuguese and English. This result suggests that an MT system is capable of facilitating the syntactic processing of a second language by allowing users to access a structure that poses a challenge to the syntactic processing mechanism of Brazilian Portuguese native speakers. In contrast, this processing facilitation triggered by the MT system was more evident at higher English proficiency levels. We hypothesize that the effect of English proficiency observed is related to the participants' focus of attention when processing the second language. A number of studies (e.g. Marinis et al. (2005)) have shown that language learners at lower levels of proficiency are less sensitive to syntax than more proficient bilinguals because they focus their attention more on resolving semantic ambiguities than on resolving parsing problems. However, at higher proficiency levels it is possible to observe more automaticity in second language parsing. Accordingly, our results suggest that MT systems can be useful in English language learning as it can facilitate end-users to access or construct problematic syntactic structures in English due to the structural differences between the languages. Moreover, based on some psycholinguistic studies (e.g. (Heyselaar et al., 2017a; Charny, 1966)) evidencing that people

## 6 General discussion and conclusions

To test the influence of MT output on the syntactic processing of English, we measured the effect of priming when performing a translation task using Google Translate. To this end, we used a common syntactic priming experimental design allowing us to compare the priming magnitude in the participant's speech before and after the task.

In line with our predictions and the literature, our results show that, after interacting with an MT system, participants tend to use the same syntactic alternative previously seen in the output of the MT system more frequently in their subsequent speech. That is, they tended to use more NP constructions after the translation task with Google Translate. Importantly, after being primed by the

tend to syntactically align more often with people they like, the priming effect observed may suggest that people enjoy interacting with Google Translate.

Although this study provides evidence for the influence of MT on English syntactic processing as a second language, especially NP structures, it also reveals the possibility that other syntactic structures may show the same effect as well as other language pairs. Therefore, in follow-up studies, we will test whether the same effect can be observed for other challenging syntactic structures for Portuguese speakers such as dative constructions with and without prepositions. In future studies, we also aim at increasing the number of participants, testing whether the popularity of the system plays a role on the magnitude of the effect and, finally, testing whether the participants mimic the Google Translate syntactic structure consciously or unconsciously. Nonetheless, we claim that this first attempt to check syntactic alignment between an MT system and MT users provides an important investigation as the methodology has been tested and produced results comparable to results found in the literature in the field of psycholinguistics, second language learning and human-computer interaction.

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## References

- Baayen, R.H., D.J. Davidson, and D.M. Bates. 2008. Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, 59(4):390 – 412. Special Issue: Emerging Data Analysis.
- Barr, Dale J., Roger Levy, Christoph Scheepers, and Harry J. Tily. 2013. Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, 68(3):255 – 278.
- Bates, Douglas, Martin Mächler, and Bin Dai. 2011. *lme4: Linear Mixed-Effects Models Using S4 Classes*, volume 0.999375-33. 01.
- Bock, Kathryn and Zenzi M. Griffin. 2000. The persistence of structural priming: Transient activation or implicit learning?. *Journal of Experimental Psychology: General*, 129(2):177 – 192.
- Bock, J. Kathryn and Antony S. Kroch. 1989. The isolability of syntactic processing. In M.K., Carlson G.N. and Tanenhaus, editor, *Linguistic Structure in Language Processing. Studies in Theoretical Psycholinguistics*, volume 7. Springer, Dordrecht.
- Bock, Kathryn, Helga Loebell, and Randal Morey. 1992. From conceptual roles to structural relations: Bridging the syntactic cleft. *Psychological Review*, 99(1):150 – 171.
- Bock, J. Kathryn. 1986. Syntactic persistence in language production. *Cognitive Psychology*, 18(3):355 – 387.
- Branigan, Holly P., Martin J. Pickering, Jamie Pearson, Janet F. McLean, and Clifford I. Nass. 2003. Syntactic alignment between computers and people: the role of belief about mental states. In Alterman, Richard and David Kirsh, editors, *Proceedings of the 25th Annual Conference of the Cognitive Science Society, July 31 - August 2 2003, Boston, Massachusetts*, pages 186–191. Lawrence Erlbaum Associates.
- Branigan, Holly P., Martin J. Pickering, Andrew J. Stewart, and Janet F. Mclean. 2000. Syntactic priming in spoken production: Linguistic and temporal interference. *Memory and Cognition*, 28(8):1297–1302.
- Charny, Israel W. 1966. Integrated individual and family psychotherapy. *Family Process*, 5(2):179–198.
- Chinnery, George. 2008. You've got some gall: Google-assisted language learning. *Language Learning Technology*, 12(1):3–11.
- Clifford, Joan, Lisa Merschel, and Joan Munné. 2013. Surveying the landscape: What is the role of machine translation in language learning? *Revista d'innovació educativa*, (10):108–121.
- Cowan, Benjamin R., Holly P. Branigan, Mateo Obregón, Enas Bugis, and Russell Beale. 2015. Voice anthropomorphism, interlocutor modelling and alignment effects on syntactic choices in human-computer dialogue. *International Journal of Human-Computer Studies*, 83:27 – 42.
- Ferreira, Victor S. and Kathryn Bock. 2006. The functions of structural priming. *Language and Cognitive Processes*, 21(7-8):1011–1029. PMID: 17710210.
- Garcia, Ignacio and María Isabel Pena. 2011. Machine translation-assisted language learning: writing for beginners. *Computer Assisted Language Learning*, 24(5):471–487.



- Gaspari, Federico and John Hutchins. 2007. Online and free ! ten years of online machine translation : Origins , developments , current use and future prospects.
- Gupta, Brij M. and S. M. Dhawan. 2019. Machine translation research a scientometric assessment of global publications output during 2007 16. *DESIDOC Journal of Library Information Technology*, 39(1):31–38, 01.
- Hartsuiker, Robert J. and Herman H.J. Kolk. 1998. Syntactic facilitation in agrammatic sentence production. *Brain and Language*, 62(2):221 – 254.
- Heyselaar, Evelien, Peter Hagoort, and Katrien Segaert. 2017a. How social opinion influences syntactic processing—an investigation using virtual reality. *PLOS ONE*, 12(4):1–21, 04.
- Heyselaar, Evelien, Peter Hagoort, and Katrien Segaert. 2017b. In dialogue with an avatar, language behavior is identical to dialogue with a human partner. *Behavior Research Methods*, (49):46–60.
- Konopka, Agnieszka E. and Kathryn Bock. 2009. Lexical or syntactic control of sentence formulation? structural generalizations from idiom production. *Cognitive Psychology*, 58(1):68 – 101.
- Levelt, Willem J.M and Stephanie Kelter. 1982. Surface form and memory in question answering. *Cognitive Psychology*, 14(1):78 – 106.
- Marinis, Theodore, Leah Roberts, Claudia Felser, and Harald Clahsen. 2005. Gaps in second language sentence processing. *Studies in Second Language Acquisition*, 27(1):53–78.
- McDonough, Kim. 2006. Interaction and syntactic priming: English 12 speakers’ production of dative constructions. *Studies in Second Language Acquisition*, 28(2):179–207.
- Niño, Ana. 2006. *Evaluating the suitability of using raw machine translation output as input for foreign language written production*. Ph.D. thesis.
- Oviatt, Sharon, Courtney Darves, and Rachel Coulston. 2004. Toward adaptive conversational interfaces: Modeling speech convergence with animated personas. *ACM Trans. Comput.-Hum. Interact.*, 11(3):300–328, September.
- Pickering, Martin J. and Holly P. Branigan. 1998. The representation of verbs: Evidence from syntactic priming in language production. *Journal of Memory and Language*, 39(4):633 – 651.
- Pickering, Martin J. and Victor S. Ferreira. 2008. Structural priming: A critical review. *Psychological Bulletin*, 134(3):427 – 459.
- Pickering, Martin J. and Simon Garrod. 2004. Toward a mechanistic psychology of dialogue. *Behavioral and Brain Sciences*, 27(2):169–190.
- R Core Development Team, R. 2011. *R: A language and environment for statistical computing*. Viena, Austria.
- Shin, Jeong-Ah and Kiel Christianson. 2012. Structural priming and second language learning. *Language Learning*, 62(3):931–964.
- Stoyanchev, Svetlana and Amanda Stent. 2009. Lexical and syntactic priming and their impact in deployed spoken dialog systems. In *Proceedings of Human Language Technologies: The 2009 Annual Conference of the North American Chapter of the Association for Computational Linguistics, Companion Volume: Short Papers*, NAACL-Short ’09, page 189–192, USA. Association for Computational Linguistics.
- Suzuki, N. and Y. Katagiri. 2007. Prosodic alignment in human-computer interaction. *Connection Science*, 19(2):131 – 141.