



Hierarchical levels of representation in language prediction: The influence of first language acquisition in highly proficient bilinguals



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ARTICLE INFO

Article history:

Received 31 March 2016

Revised 22 November 2016

Accepted 24 March 2017

Available online 3 April 2017

Keywords:

Prediction

Multilingualism

N200

Beta-band activity

Reading

ABSTRACT

Language comprehension is largely supported by predictive mechanisms that account for the ease and speed with which communication unfolds. Both native and proficient non-native speakers can efficiently handle contextual cues to generate reliable linguistic expectations. However, the link between the variability of the linguistic background of the speaker and the hierarchical format of the representations predicted is still not clear. We here investigate whether native language exposure to typologically highly diverse languages (Spanish and Basque) affects the way early balanced bilingual speakers carry out language predictions. During Spanish sentence comprehension, participants developed predictions of words the form of which (noun ending) could be either diagnostic of grammatical gender values (transparent) or totally ambiguous (opaque). We measured electrophysiological prediction effects time-locked both to the target word and to its determiner, with the former being expected or unexpected. Event-related (N200–N400) and oscillatory activity in the low beta-band (15–17 Hz) frequency channel showed that both Spanish and Basque natives optimally carry out lexical predictions independently of word transparency. Crucially, in contrast to Spanish natives, Basque natives displayed visual word form predictions for transparent words, in consistency with the relevance that noun endings (post-nominal suffixes) play in their native language. We conclude that early language exposure largely shapes prediction mechanisms, so that bilinguals reading in their second language rely on the distributional regularities that are highly relevant in their first language. More importantly, we show that individual linguistic experience hierarchically modulates the format of the predicted representation.

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1. Introduction

The neural system strongly relies on feedback-recurrent neural projections to interact with evidence from the environment (Arnal, Doelling, & Poeppel, 2015; Bastos et al., 2015; Michalareas et al., 2016). This supports the idea that much of our brain activity focuses on the prediction of upcoming sensory information rather than its passive integration, and that the system mainly encodes only the unpredicted portion of the sensory signal (Bar, 2007; Clark, 2013; Friston, 2005). Predictive processes thus are a valuable resource contributing to the ease and speed with which language comprehension incrementally builds upon contextual information and internal knowledge (Federmeier, 2007; Levy, 2008; Pickering & Garrod, 2013). Some authors consider prediction so fundamental

that it has been suggested that learning to speak in infants arises directly from learning to predict (Mani & Huettig, 2012). Even so, the role of internal linguistic knowledge and more specifically of early language exposure in modulating prediction across different speakers has not been adequately studied. In the present study we focus on this topic, evaluating how multilingual experience (and more specifically native language knowledge) affects language prediction (e.g., Chang, Dell, & Bock, 2006).

Research on language prediction in bilinguals has provided clear evidence that low proficiency second language (L2) speakers who cannot rely on life-long experience consequently have not developed robust prediction processes, as native (L1) speakers do (for a review, Kaan, 2014). Factors such as reduced proficiency and reduced experience make language prediction in L2 “weaker” than in L1. Nonetheless, if proficiency levels are balanced, prediction in L2 should be similar to prediction in L1 (e.g., Hopp, 2013). In the present study we test this hypothesis, focusing on the prediction abilities of balanced Basque-Spanish speakers who have

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been primarily exposed (before age of 3) to one of the two languages, but are fluently proficient in both. Focusing on these populations, we study how the language background provided by the early language exposure affects language prediction. We show that when L2 proficiency is high, prediction in L2 is not necessarily equivalent to prediction in L1, since it is sensitive to the typological characteristics of the native language of each speaker. This can trigger anticipations of even more specific linguistic representations for non-native compared to native speakers.

1.1. Bilingual prediction

There are multiple factors which affect prediction in a second language (Kaan, 2014). The role of proficiency has been highlighted in a series of studies employing the visual word eye-tracking paradigm (see Altmann & Kamide, 1999, for evidence of prediction in natives). Mitsugi and MacWhinney (2015) reported that non-native Japanese learners did not show predictive saccades during speech listening, as native speakers do. On the other hand, Hopp (2013) reported that English learners of German show such predictive looks if they are proficient enough in German. Complementary evidence comes from the ERP (Event-Related Potentials) sentence comprehension literature. In a recent study, Martin et al. (2013) studied language prediction in L2 similarly to DeLong, Urbach, and Kutas (2005) who provided evidence of prediction in natives. In the former study, while reading sentences such as *The day was breezy so the boy went outside to fly...* L2 late English speakers did not show a lexical prediction effect (i.e., a modulation of the N400 ERP component, assumed to reflect lexical/semantic processing) for determiners (*a*) that match a following highly expected noun (*kite*) compared to determiners introducing a low expected noun (*an* introducing *airplane*).

While proficiency appears to be a critical factor modulating prediction, interaction of the predicted representations with the ones available in the native language has also been shown to be relevant. Foucart, Martin, Moreno, and Costa (2014) observed that both early Spanish-Catalan and late French-Spanish bilinguals showed prediction effects during sentence reading, as did Spanish monolinguals (see Wicha, Moreno, & Kutas, 2004, for evidence of prediction in natives). The authors recorded ERPs time-locked to a gender-marked determiner preceding a highly expected noun in sentences such as *El pirata tenía el mapa pero no encontró...* (“The pirate had a map but did not find...”). The following determiner could either gender-match with the predicted Spanish noun (such as the grammatically masculine determiner *el* preceding *tesoro* – “the treasure”), or it could gender-mismatch with the predicted noun (the feminine *la*, introducing a non-anomalous noun such as *gruta* – “cave”). This study thus highlights that L1–L2 similarity (both French and Catalan have grammatical gender, as does Spanish) boost language prediction, independently of language proficiency (early or late L2 speaker).

Individual differences (Dussias & Pinar, 2010; Kaan, 2014) and task-related processing strategies (Ferreira, Foucart, & Engelhardt, 2013; see also Clahsen & Felser, 2006) are additional elements shown to modulate language prediction. An important point raised by Kaan (2014) is that differences in prediction between native and second language speakers are mainly due to the same factors that account for individual differences in natives. We here provide a step further in the research on bilingual prediction. Until now, most studies have focused on the presence/absence of prediction effects in late/low proficiency bilinguals. We here accept Kaan's position, that prediction is possible in L2 providing proficiency levels are high enough. One unsolved issue in such a scenario, however, is what kind of prediction bilinguals develop: Is prediction fully tuned to the properties of the L2 or can we find traces of influence from the native language? In other words, is prediction

mainly a question of proficiency, or is there any influence of the language background even in highly proficient early L2 readers?

Studies on highly proficient bilinguals so far have not answered this question. In Foucart et al. (2014) there was no reason for Catalan-Spanish bilinguals to show differences from the native Spanish speakers, since Catalan and Spanish are typologically highly similar and share an overlapping gender system. Hopp (2013) did report similar prediction effects for English-German bilinguals and German natives, but that experimental paradigm was not designed to highlight differences of prediction in the two groups. Here, we focus on balanced Basque-Spanish bilinguals who are Basque natives (compared to Spanish-Basque bilinguals), since the large typological difference between the two languages could affect the way prediction processes are at work in the two groups while they process Spanish sentences.

This study on prediction in bilinguals can inform research on language prediction, since it focuses on the link between the language background of a speaker and the way prediction abilities develop during comprehension. In addition, based on the observation that prediction has considerable advantages for learning (Rescorla & Wagner, 1972; Schultz, Dayan, & Montague, 1997; see also Kuperberg & Jaeger, 2016), it is relevant for language learning research to evaluate how multilingual experience modulates language prediction.

1.2. The present study

In the present study, Basque (L1)-Spanish (L2) and Spanish (L1)-Basque (L2) very early bilinguals read Spanish sentences word by word for comprehension. We tested participants who were highly proficient in Spanish but were primarily exposed either to Spanish or to Basque before the age of 3. We avoided the comparison between monolinguals and bilinguals since this latter group has a huge amount of competing linguistic information (another language) that can alter the prediction processing dynamics as compared to monolinguals. The present design, comparison between two groups of early balanced bilinguals, resolves this confound.

The interaction between Spanish and Basque was considered as highly informative to address our research question. Spanish and Basque are two rich-morphology languages that are, however, typologically very different on a large number of dimensions (mainly lexical and syntactic). A relevant difference is the way in which these two languages instantiate the relation between content and function words. As an example, determiners (articles, quantifiers and prepositions) precede their nouns in Spanish (*la mesa*, “the table”), while in Basque these function words are consistently implemented as post-nominal bound suffixes (*mahai-a*, “the table”; de Rijk & de Coene, 2008; for corpus evidence, Gervain et al., 2013). These functional elements are relevant, since they are prominent cues for speech segmentation and signal syntactic boundaries within a sentence. This difference makes Basque speakers focus more on the morphological structure of nouns, given their syntactic diagnosticity, and more specifically on noun endings (both infants, Molnar, Lallier, & Carreiras, 2014, and adults, Gervain et al., 2013).

Based on this typological distinction, the present study capitalized on bilingual sensitivity to the “unsystematic” distributional properties of grammatical gender, a feature that is present in Spanish but not in Basque. In Spanish inanimate nouns, grammatical gender is an arbitrary feature (either masculine or feminine) that is uniquely assigned to individual lexical items. This feature is informative of structural relations such as the one between a determiner and its head noun (see Foucart et al., 2014, study described above) and it has been used to study lexical prediction during sentence processing (Wicha et al., 2004). Intriguingly, noun

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