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Tuning to languages: experience-based approaches to the language science of bilingualism

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Abstract:
Experience-based approaches to language hold that individuals become sensitive to distributed emergent phenomena in their linguistic experience. The purpose of this paper is to bring together experience-based perspectives from the domains of cognitive psychology and linguistics. First, we present an overview of the cognitive processes that underpin experience-based learning, and review the cognitive biases that have been attributed to the emergence of distributional regularities in language. We then discuss the P-chain (Dell, G. S. & F. Chang. 2014. The P-chain: Relating sentence production and its disorders to comprehension and acquisition. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 369(20120394). 1–9.), an influential experience-based framework for experience-based theory in psycholinguistics, and present data from bilingual speakers to substantiate the assumptions of the model. Our goal is to focus on language usage in bilinguals to illustrate how individuals can become attuned to linguistic variation in the input and how this input can act as constraining information with critical psycholinguistic implications.

Keywords: bilingualism, experience-based approaches, language processing

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1 Introduction

Language research under an experience-based framework covers the interaction between the dynamics of human behavior and domain-general cognitive processes in relation to language representation, processing, and experience (Langacker 1987; Croft 1991; Givón 1995; Tomasello 2003; Bybee 2010; Goldberg 2006; MacDonald 2013). Under this perspective, language is viewed as a complex adaptive system that emerges from a more general system mediating action control. A basic premise of experience-based approaches is that learning and plasticity occur in response to recurrent demands on cognitive processes. While non-verbal experiences such as learning to play an instrument, video gaming, or juggling have been found to influence cognitive functions (Draganski et al. 2004; Bialystok and Depape 2009; Bavelier et al. 2012), the acquisition and regular use of language in day-to-day interactions is a particular stimulating experience involving demanding action sequences in terms of their planning and execution (Green and Abutalebi 2013; Kroll and Navarro-Torres in press).

A feature of bilingualism is that it increases the demands on the processes involved in everyday discourse over and above the language experiences of monolinguals (Green and Abutalebi 2013). Traditionally, bilingualism has not been a mainstream research topic because it has been considered by some to be a complicating factor for the language system. Our standpoint is that the bilingualism experience is necessarily complex: recent studies make clear that the continual interplay between languages involves a dynamic set of adaptive changes across the lifespan (Kroll et al. 2015). Crucially, though, complexity does not equate to being complicated. Far from it being considered a special circumstance, bilingualism may provide a lens through which the constraints and plasticity characterized by experience-based approaches can be fully understood. Over and above the variability observed in monolingual contexts, the heterogeneity in linguistic exposure experienced by bilinguals affords unique opportunities to observe the consequences of language experience by testing how the different interactional and linguistic contexts in which bilinguals find themselves modulate language processes.

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This paper presents an overview of the cornerstones of experience-based approaches. First, we review the cognitive processes and biases that have been attributed to the emergence of distributional regularities in language. We then discuss the P-chain (Dell and Chang 2014), an influential framework for experience-based theory in psycholinguistics. Finally, we apply the assumptions of the P-chain to explain recent empirical findings with special emphasis on bilingualism.

2 Experience-based learning

Sensitivity to probabilistic information is an ability found in many species. For example, rats' behavior in a T-shaped maze reveals high sensitivity to the rate at which certain probabilistic events occur (e.g. a reward; Gallistel 1990). Just like rats' behavior is based on detection of rate of food source, humans have the ability to adapt to the likelihood of different events by learning to use probabilistic cues in their environment (Kelly and Martin 1994). There is evidence from the domains of cognition and perception that humans are sensitive to relative frequency of occurrence of information in non-verbal (Hasher and Zacks 1984) and linguistic contexts (e.g. the word superiority effect in which letters are perceived more accurately in the context of a word than in isolation; Reicher 1969; Johnston 1978). Recent proposals argue that the mechanism underlying this domain-general ability represents a basic aspect of implicit learning (Dell and Chang 2014; Ellis et al. 2015). Learning is achieved through the associative process of weighing the probabilities of occurrence of prototypical patterns in individuals' experience (Bybee 2010). In the manner that increases in frequency of occurrence of an event reduce the reaction time needed to perform an action, distributional linguistic information impacts language form and language processing (Bates and MacWhinney 1982; MacDonald et al. 1994).

Individuals learn the words embedded in a speech stream by learning the transitional probabilities between syllables to hypothesize word boundaries (Saffran et al. 1996), and there is ample evidence demonstrating that frequently-occurring patterns are preferred and processed more fluently over less common forms and structures (Mitchell and Cuetos 1991; Ellis 2002). These effects are compatible with constraint-satisfaction accounts of language processing (MacDonald and Seidenberg 2006) which posit that comprehension is based, not on syntactic heuristics that require sequential stages of processing (Frazier 1979; Hahne and Friederici 1999; Newmeyer 2006), but on individuals' ability to exploit probabilistic information.

How do regularities in language emerge? Under experience-based frameworks, the organization and productivity of language is understood as the result of conventionalized form-function mappings at varying levels of complexity and abstraction (Goldberg 2013). The linguistic unit that characterizes these cross-modal associations is the construction, a unit built up from stored exemplars of previous experience (e.g. the ditransitive construction "X causes Y to receive Z"; Langacker 1987; Fillmore 1988; Goldberg 2006). Constructions become generalized through the interaction of cognitive mechanisms during language use in particular language contexts (Bybee 2010). Crucially, because constructions are subject to cognitive constraints, domain-general processes such as categorization and analogy (Bybee 2010) are presumed to shape the distributions of language form, structure, and variance.

3 Cognitive constraints on language form

Throughout her influential work, Bybee (2013) has identified several cognitive processes that underpin experience-based approaches. Although these cognitive processes influence language structure and contribute to the creation and entrenchment of constructions, they also function in other areas of domain-general cognition. Several processes of human cognition have been identified to influence and constrain the language system. *Categorization*, the process of arranging objects and ideas into categories in which they are recognized and differentiated, is one of them (Cohen and Lefebvre 2005). Category membership is gradient, with some objects considered better members than others (Rosch 1977). Studies have shown that object categorization is exemplar-based and can be facilitated based on the similarity to even marginal category members (Medin and Schaffer 1978). In a study of abstraction of visual patterns, Franks and Bransford (1971) found that participants were likely to misrecognize shapes that had matching features to previously observed exemplars, but that had not been shown during the experimental session. The findings suggest that participants were able to build up an abstract prototype of a category based on stored exemplar information. On a similar vein, phonemes, morphemes, and words are linguistic categories in which similar instances of use are categorized into more abstract representations (Langacker 1987). Categorization is also involved in *analogy*, the process through which abstract connections between items are formed (Gentner 1983). Analogy underpins the mapping between abstract representations by systematically extending prototypical meanings in an existing pattern to novel items based on

stored exemplar information (Winston 1980; Bybee 2010). In this way, analogy-driven learning enables generalization and accounts for language productivity. Bybee and Eddington (2006) elaborate on this process in their analysis of instances of verb+adjective sequences in which novel instances (e.g. in Spanish, *ponerse+ciego* 'to go blind') appear to be formed onto existing high-frequency conventionalized instances (e.g. *ponerse+nervioso* 'to become nervous'). *Chunking*, the process of grouping familiar sequences into units, is widespread across species (Miller 1956; Simon 1974). For example, zebra finches are able to learn songs by extracting strings of consecutive syllables and then singing these chunks together (Williams and Staples 1992). Chunks are formed when units develop a sequential relation through repetition or practice and are recalled more easily than unfamiliar sequences (Terrace 1987). The process of chunking leads to the formation of constructions and formulaic expressions that can be accessed together rather than compositionally (e.g. 'take a break'; Bybee 2013) leading to performance improvement with greater practice or frequency (Anderson 1982). The internal structure of chunks is based on associations between sequences, and the strength of such associations is based on the transitional co-occurrence between individual elements. As sequential units become more frequent, their meanings become more non-literal rather than compositional (see Christiansen and Chater 2015, for a review).

According to (Bybee 2010, 2013), frequent use of chunks weakens their composability but strengthens their representation in memory. A *rich memory storage* keeps track of tokens of language experience including details associated with specific linguistic contexts. Among the list of processes that affect language, the ability to make cross-modal associations accounts for the way sources of information are integrated in the processing of linguistic patterns. Individuals make associations not only between meaning (i.e. a particular concept) and form (i.e. choice of a particular linguistic expression), but also between language and the context in which it is used. In this way, the language system faces the task of keeping track of not only frequency of words and the syntactic structure they are part of, but also of the co-occurrence relations between them (Gahl and Garnsey 2004; Jaeger 2006; Tily et al. 2009).

In addition to these principle domain-general cognitive processes, mechanisms and biases involved in utterance planning are thought to create typological distributions in languages (Jaeger and Tily 2011; MacDonald 2013). In analogy to other behaviors, speaking entails the development and maintenance of an utterance plan that is cognitively demanding (Acheson and MacDonald 2009; Kemper et al. 2011). Individuals are biased to conform to these choices to minimize difficulty during utterance planning (e.g. interference control or retrieval access during retrieval; MacDonald 2013) and maximize production fluency (Jaeger and Tily 2011). Although these biases are not specific to language, they do help shape the distribution of utterance forms in language (e.g. word order choice; Bock and Warren 1985) as well as determine important aspects of language comprehension. A characterization of such biases is illustrated in the tendency for items that are more accessible to appear both earlier in utterances and at more salient syntactic structures than items that are more difficult to retrieve. This is exemplified in the preference for individuals to speak of previously mentioned information before introducing new information in the discourse (Bock and Irwin 1980; Ferreira and Yoshita 2003; Tanaka et al. 2011) or in the tendency to minimize dependency length (Stallings et al. 1998; Yamashita and Chang 2001).

A second cognitive bias underlying utterance planning is evident in studies of priming or memory recall in which individuals tend to reuse or recall recently experienced utterance plans (Ferreira and Bock 2006). For example, individuals' expectation of encountering a passive structure is said to increase if they have recently heard or uttered another passive structure, and this effect is strongest with less common structures (Bernolet and Hartsuiker 2010).

A third cognitive bias is reflected in individuals' strategies to reduce interference of competing items during utterance planning. Because language production entails the activation of competing alternatives, utterances containing semantically-related items are more difficult to plan and are more prone to interference-based errors (e.g. 'We have *pons* and *pats* to wash'; Garrett 1980; Smith and Wheeldon 2004). There is empirical evidence suggesting that individuals mitigate these consequences via choices of utterance form. In a cross-linguistic study of active and passive structures in English, Spanish, and Serbian, Gennari et al. (2012) found that similarity-based competition had an impact on individuals' structural choices. Results indicated that for all languages, omission of the agent correlated with the degree similarity-based competition between the agent and the patient. Furthermore, the actual choice of structure (i.e. passive or active) was constrained by language-specific grammatical options: while English speakers preferred the use of passive structures, Spanish and Serbian speakers used active structures in which omission of the agent is permissible. Crucially, the repetition of these choices across utterances and across individuals creates typological distributions that are then implicitly learned by language users. The evidence across these studies provide support for experience-based models of language processing in which it is claimed that language is represented and processed similarly and on the basis of experience.

However, according to Ibbotson (2013), linguistic structure may also be culturally constrained beyond domain-general cognitive processes previously discussed. Language use is said to stem from an interactional context of normative agreements and cooperative reasoning. Ibbotson establishes this argument with examples of communities that have reportedly changed aspects of their language (e.g. gender agreement in New

Guinean communities; Kulick 1992). We also know that language variation is often conditioned by sociolinguistic variables (Labov 2010). In bilingual speakers, codeswitching, the alternation between languages, is a structured and creative linguistic behavior that is often dependent on group membership and that arises in some bilingual communities but not in others (Poplack 1980). Understanding the interaction between cognitive and cultural constraints may help determine the orchestration of the mechanisms involved in linguistic tuning. In what follows, we elaborate on the consequences of constraint-based learning on language processing as subsumed by an emerging framework for experience-based theory in psycholinguistics: the P-chain. This paper is not intended as a comprehensive critique of the P-chain. Rather, the goal is to elaborate on its propositions and discuss applications of the framework to recent bilingual data.

4 An experience-based framework of language processing: the P-Chain[1]

The P-Chain (Dell and Chang 2014) is a conceptual framework of interrelations among psycholinguistic concepts such as production, comprehension, and learning. The role of prediction in implicit learning is central to the P-chain. As an utterance incrementally unfolds, language processes generate predictions regarding upcoming information. Linguistic expectations are guided by distributional assumptions that are based on individuals' previous language experience. Adaptive adjustment is said to occur when expectations are not met, and is made in the form of implicit learning. Implicit learning in this context is the mechanism for adaptation of language processing which is intrinsically linked to individuals' input history. This adaptation is also manifest in production on grounds of individuals' inferences on which utterances are based. In other words, production processes are modulated by individuals' ability to generate predictions. In this way, production and comprehension processes are linked and affected by previous linguistic experience.

4.1 Linking production and prediction

Linguistic prediction allows individuals to link what comprehenders expect to hear with what speakers actually say. The P-chain framework assumes a strong connection between production and prediction skill and hypothesizes that predictions are generated by comprehenders' previous experience processing a particular linguistic input. Comprehenders have been shown to be skilled not only at generating predictions at points in a sentence about upcoming words (meaning; DeLong et al. 2005), but also about the upcoming structures (syntax; Staub and Clifton 2006) that they will encounter as an utterance unfolds (Altmann and Mirković 2009). For example, research on grammatical gender has shown that speakers are skilled at using morpho-syntactic information to facilitate spoken language processing (Dussias et al. 2013). This gender anticipatory effect is typically examined by measuring eye movements to referenced objects during auditory comprehension, reflecting individuals' real-time processing commitments. In the Spanish version of this paradigm, participants see a visual scene consisting of two objects while they listen to instructions to click on one of the objects (e.g. *Encuentra el* X, English: 'Find the$_{\text{MASC}}$ X'). Masculine- and feminine-gendered target items are preceded by an article that agrees in gender with the two objects (i.e. same-gender contexts; e.g. *tenedor* and *cuchillo*, English: 'fork$_{\text{MASC}}$' and 'knife$_{\text{MASC}}$') or only with one of the objects (i.e. different-gender contexts; e.g. *tenedor* and *cuchara*, English: 'fork$_{\text{MASC}}$' and 'spoon$_{\text{FEM}}$'). The gender anticipatory effect in different-gender contexts has been reported for monolinguals across gendered languages (e.g. Spanish, Lew-Williams and Fernald 2007), but findings for bilinguals have been mixed (Lew-Williams and Fernald 2010; Dussias et al. 2013). Although the patterns of variation observed in grammatical gender processing have long been a topic of interest and discussion in the psycholinguistic literature, only recently have studies turned their attention to examining differences as a function of language experience and use.

An eye-tracking study by Valdés Kroff et al. (2017) proposed that codeswitching experience may modulate bilinguals' sensitivity to gender as an anticipatory processing cue. The rationale for their hypothesis was based on well-documented codeswitching behavior: Spanish-English bilinguals who engage in codeswitching exhibit an overall preference to use the masculine determiner *el* 'the$_{\text{MASC}}$' with English nouns whose translations equivalents in Spanish are masculine or feminine (Lipski 1978; Pfaff 1979; Valdés Kroff 2016). Conversely, switches involving the feminine determiner *la* 'the$_{\text{FEM}}$' occur less frequently and are restricted to English nouns that are feminine in Spanish. To illustrate, *el*-codeswitches such as '*el* fork' (*tenedor*$_{\text{MASC}}$) and '*el* spoon' (*cuchara*$_{\text{FEM}}$) are copious. To a lesser extent, *la*-codeswitches involving feminine nouns '*la* spoon' have also been attested in bilingual speech, but those involving masculine nouns – '*la* fork' – have not. If prediction skill is tied to individuals' production preferences, codeswitching bilinguals should only exploit feminine gender as a cue in comprehension. Using the aforementioned eye-tracking paradigm, Valdés Kroff et al. reported that whereas Spanish monolinguals could use both masculine and feminine grammatical gender as a facilitatory cue in sentence pro-

cessing, Spanish-English codeswitchers only exhibited anticipatory effects in feminine-determiner conditions, which mirrored the asymmetric use of gender observed in the codeswitching communities where participants were from.

4.2 Prediction error leads to implicit learning

According to the P-Chain framework, when generated expectations are not met, the language processing system must adjust to reduce future prediction error. This proposition is evidenced in the priming literature, where it has been found that more surprising structures lead to stronger priming (Bernolet and Hartsuiker 2010). The idea that priming induces learning is exemplified in a study by Bock et al. (2007) where it was found that comprehending a particular structure affected the production of later utterances. Crucially, this effect persisted across several trials and even across different modalities (Bock and Griffin 2000). Bock and colleagues suggest that the mechanism through which structural priming undergoes adaptation is a form of implicit learning. This sensitivity to experienced sequences is said to be implicit because although individuals are able to keep track of the likelihood that items occur in particular structures, they are able to do so independently of explicit awareness of this knowledge (Reber 1967, 1989). As Reber suggests, implicitly acquired knowledge can be extended to novel circumstances, explaining how statistical probabilities can change over time.

While learning from prediction error is a fundamental process in individuals of all language backgrounds (Clark 2013), how it gets deployed may be a function of individuals' language experience. In a recent study, Hopp (2016) tested whether variability in L2 gender agreement processing lead to the abandonment of processing strategies in second language learners of German. To probe lexical gender assignment, participants first underwent a picture description task where they were asked to produce determiner-noun sequences of visually displayed objects. After the production task, participants completed a visual world experiment to test the predictive processing of gender agreement. It was found that correct gender assignment in production correlated with predictive gender processing in comprehension. To test whether prediction failure was a result of error-driven implicit learning, Hopp conducted a follow-up study with native speakers of German under L2-like input conditions. In a pre- and post-test design, one group of native speakers received target gender assignment and the other received filler items with non-target gender assignment. In support of the P-Chain, the study found that while native speakers who had received target input continued to use gender assignment predictively, the non-target input group had abandoned using gender as a cue when gender assignment was no longer reliable. The idea behind this finding is that if a prediction is not properly met, individuals must adapt and readjust their knowledge to maximize future predictive success.

4.3 Implicit learning leads to adaptation and acquisition

Recent findings suggest that short-term exposure to particular structures can also lead to adaptation of speakers' processing strategies. In an eye-tracking study investigating relative clause ambiguity resolution (Perrotti et al. 2015), Spanish-English bilinguals underwent an intervention in which they were exposed to sentences with relative clauses (e.g. *Miguel localizó a la amiga del peluquero que era griega* 'Miguel located the friend of the hairdresser who was Greek'). A pretest measured the participants' baseline parsing preferences. Next, participants underwent an intervention during which they read stories in which the syntactic ambiguity was resolved by high attachment (e.g. *Miguel localizó a la amiga del peluquero que era griega* 'Miguel located the friend$_{FEM}$ of the hairdresser$_{MASC}$ who was Greek$_{FEM}$') or by low attachment (e.g. *Miguel localizó a la amiga del peluquero que era griego* 'Miguel located the friend$_{FEM}$ of the hairdresser$_{MASC}$ who was Greek$_{MASC}$'). Participants returned to the lab for two posttests conducted immediately and one week following the intervention respectively. The results showed that participants had switched original attachment preferences after the intervention and maintained the adapted preference by the second posttest. These findings therefore suggest that adaptation to short-term exposure is not necessarily short-lived.

4.4 Production provides the input for training processing

The P-Chain model proposes that the input for training processing is based on the production-based processes that affect the likelihood, and hence the distributions, of particular linguistic structures. The distributional patterns that arise from these processes act as probabilistic constraints which in turn shape the comprehension system. This last proposition is further elaborated in a recent experience-based model of language production and comprehension, the Production-Distribution-Comprehension (PDC) model (MacDonald 2013). MacDonald proposes that individuals' linguistic choices are influenced by implicit strategies to mitigate production

difficulty and are experience-based. Over time, distributional patterns become widespread and customary in a community of speakers in a constraint-based fashion. Comprehension difficulty is thus linked to the probability of upcoming information, and interpretation preferences can be traced to individuals' distributional choices as determined by production mechanisms. The goal of the PDC model is to explain how these distributional patterns emerge and how learning of those regularities influences individuals' expectations about upcoming information during comprehension.

To illustrate an example in bilingual contexts, Guzzardo Tamargo et al. (2016) examined codeswitchers' sensitivity to production asymmetries involving Spanish-English codeswitches at the auxiliary+participle phrase. They compared codeswitches involving progressive and perfect structures. Their quantification of these two structures in a bilingual corpus, revealed that codeswitches at the former site were more frequent than those at the latter site. The processing of these two structures was subsequently tested in an eye-tracking study with bilingual codeswitchers. Participants' comprehension costs were found to mirror the production patterns found in codeswitching corpora, i.e. frequently-attested codeswitches were read more efficiently than those rarely-attested.

Lastly, to examine whether this sensitivity is not language-specific but rather determined by individuals' particular linguistic experiences, Beatty-Martínez and Dussias (2017) compared two groups of Spanish–English bilinguals who differed in codeswitching experience (codeswitchers from a habitual codeswitching community and non-codeswitchers). To examine whether adaptation to different interactional contexts modulated the processing of codeswitches, an ERP experiment compared the processing of different types of codeswitches that were either rarely-attested or commonly-attested in bilingual corpora. For codeswitchers, rarely-attested codeswitches elicited an N400 effect in comparison to common codeswitches, suggesting greater difficulty with lexical integration. Non-codeswitchers, on the other hand, processed these two types of codeswitches similarly. Furthermore, non-codeswitchers showed an early positive modulation of EEG activity to switching, regardless of switch type, most likely reflecting detection of a language change during early monitoring stages of language processing. The same two groups additionally completed a codeswitching map task (Beatty-Martínez et al. 2017) to assess their spoken codeswitching ability. Codeswitchers switched more often than non-codeswitchers, and their switches robustly reflected the conditions that were more easily processed in the ERP study. Together, the results demonstrate that the comprehension system becomes optimally attuned to variation in the input, by providing evidence of how individuals' experience-based expectations predict comprehension performance. Particularly regarding codeswitching, the findings underscore how the processing of codeswitched language largely depends on the type of codeswitches available in the participants' discourse environment and on their language experience. This is an important new finding that might have been overlooked if the study had not compared bilingual speakers who differed in their exposure to particular distributional regularities.

In this paper, we presented the goals and predictions of the experience-based framework. We discussed the evidence supporting how bilingual individuals are highly sensitive to the constraints of their language experience, as well as the link between production and comprehension processes. Individuals' ability to learn and keep track of probabilistic information is a remarkable feat, and a closer inspection of adaptation of this tuning mechanism can shed light on others aspects of human cognition more generally.

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Notes

1 We thank an anonymous reviewer for pointing out that the literature summarized in this section is mostly based on comprehension. While these studies may not specifically focus on production, their theoretical motivation and experimental design are based on aspects of production such as perceivers' own utterances and production-based distributional regularities. The basic premise of the P-chain framework is that variation in processing is best illustrated by taking into account individuals' prior linguistic experience, thus linking comprehension to production.

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