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Evidence from neurolinguistic methodologies: Can it actually inform linguistic/language acquisition theories and translate to evidence-based applications?: — Source link

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Evidence from neurolinguistic methodologies: Can it actually inform linguistic/ language acquisition theories and translate to evidence-based applications?

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Abstract

This special issue is a testament to the recent burgeoning interest by theoretical linguists, language acquisitionists and teaching practitioners in the neuroscience of language. It offers a highly valuable, state-of-the-art overview of the neurophysiological methods that are currently being applied to questions in the field of second language (L2) acquisition, teaching and processing. Research in the area of neurolinguistics has developed dramatically in the past twenty years, providing a wealth of exciting findings, many of which are discussed in the papers in this volume. The goal of this commentary is twofold. The first is to critically assess the current state of neurolinguistic data from the point of view of language acquisition and processing—informed by the papers that comprise this special issue and the literature as a whole—pondering how the neuroscience of language/processing might inform us with respect to linguistic and language acquisition theories. The second goal is to offer some links from implications of exploring the first goal towards informing language teachers and the creation of linguistically and neurolinguistically-informed evidence-based pedagogies for non-native language teaching.

Introduction

Research into linguistic and language acquisition theories and teaching spans a number of theoretical approaches, and with researchers working from within a range of different of disciplines. Despite the different perspectives taken, historically, those interested in linguistic theory and language acquisition have been largely concerned with (the development of) linguistic representations and the architecture of the language faculty. This focus on language development dovetails nicely with part of the remit of researchers focused on language teaching, who also deal with the dynamic unfolding nature of the mental realisation of language learning processes. Ideally, there would be a symbiotic relationship for mutual benefit between the cognitive/linguistic science of language acquisition and evidence-based informed language teaching practice, as is sometimes the case (see, e.g., Ellis, 2010; Lightbrown, 2000; Long & Rothman 2013; Spada 2005; Whong, 2011; Whong, Gil & Marsden, 2013). This shared goal of understanding the developmental processes of language learning contrasts with the goals of the typical neurolinguist, who alternatively addresses neuroanatomical/localization questions and those relating to the neural correlates associated with processing linguistic information, rather than linguistic competence per se. Notwithstanding crucial and necessary delineations within the centre of attention of the research that keep these fields separate, there is considerable overlap between them and opportunities for cross-fertilization. Nevertheless, to date there has been surprisingly little dialogue between linguists/acquisitionists and neurolinguists. It is, therefore, a challenge to attempt to link neurolinguistic findings to key questions and issues that are of central concern to linguistic and language acquisition theorists. Despite this, the endeavour is of great importance, and such interactions between fields have the potential to greatly enrich both.

This special issue comprises papers focusing on the topic of (the development of) grammatical knowledge, and which therefore speak to issues that lie at the heart of much theorizing in linguistics and language acquisition, as well as having clear implications for language pedagogy. As regards L2 acquisition of morphosyntax, many researchers (theorists, acquisitionists, educationalists) are concerned with mental linguistic representations: how they may be similar in L1 and L2 ultimate attainment or maturationally conditioned to be different (e.g., Bley-Vroman, 1989, 2009; Jiang, 2004; 2007;Lardiere, 2007; Tsimpli & Dimitrakopoulou, 2007; White, 2003). Age effects have been extensively studied (see, e.g., Birdsong, 1992; Bylund, Hyltenstam & Abrahamsson, 2013; Long, 2013; Muñoz & Singleton, 2011; Rothman, 2008). Some argue that features not present in the L1 (at least some) will be unacquirable after a certain age (cf., the Critical Period Hypothesis, Lenenberg, 1967; see, e.g., Franchescina, 2005; Hawkins & Liszka, 2007; Tsimpli & Dimitrakopoulou, 2007, for theoretical linguistic accounts) or ultimately acquirable, but reflecting a developmental sequence different than child L1 acquisition due at least in part to influence of previously acquired linguistic representations (e.g., Schwartz & Sprouse, 1996; White, 2003) and other secondary factors that distinguish children from adults. For example, it has been suggested that phenomena requiring integration of information across linguistic and domain-general cognitive modules (e.g., between discourse/pragmatics and syntax) are more problematic for L2 learners due to an emerging effect bilingualism entails for the use of finite cognitive resources (see, e.g., Sorace, 2011). Other L2 researchers investigate how multilingual speakers acquire and regulate more than one language in production and comprehension (e.g., Gullberg, Indefrey & Muysken, 2009; Rothman, 2015). Of great theoretical interest is the mental architecture of language, that is, whether linguistic knowledge is informationally encapsulated (e.g., Fodor, 1979) or part of general cognition (e.g., Tomasello, 2003), and what the nature of the relationship is between linguistic knowledge and real-time processing in comprehension and production (e.g., Dekydtspotter & Renaud, 2014; Roberts & Liszka, 2013). Linked to this latter topic is the question of *explicit* (consciously-accessible) versus *implicit* knowledge (e.g., Ellis, 2005, Ullman, 2004)—can the former ever become the latter—and the extent to which pedagogical interventions can impact either type (e.g., Robinson, 2005). Finally, researchers are also concerned with the effects of individual differences (in cognitive capacity, proficiency, aptitude) on the rate and ultimate success in the L2 acquisition of syntax (e.g., DeKeyser, 2012; Roberts & Meyer, 2012; Robinson, 2012). Given this vast range of theoretical topics, it is unsurprising that current neurolinguistic research has not yet been able to speak to all of them. Below we set out (1) some of the currently available neurolinguistic evidence/insights that can be applied to some of these questions, focusing in particular on the papers in this special issue; (2) limitations of the current methods and findings, and (3) some suggestions for how behavioural language experts and neuroscientists focusing on language might work together in the future to address critical questions on the topics of the nature of linguistic knowledge representation, processing and development in the first instance, and together interact more productively with language teaching.

Neurolinguistic findings

ERP evidence for language processing

As is the case with much of the research presented in this special issue, the majority of the neurolinguistic studies undertaken with L2 learners and bilinguals[i] on processing above the level of the word has used the EEG methodology, investigating the extent to which event-related potential (ERP) components elicited by various types of anomalies (semantic/syntactic) are comparable between learners and native speakers (see Kaan, 2009, for an overview). ERP work in L1 and L2 research often involves the investigation of the processing of agreement violations (e.g., subject-verb agreement in English; grammatical gender agreement in Romance, or case agreement in German). This is of great interest to theorists in linguistics and L2 acquisition who are interested in core syntactic knowledge, since agreement is assumed to be a core aspect of syntax (cf., Chomsky, 2001), as well as for language teachers, since it has been long noted that morphological realisation is one of the most problematic areas for second language learners, at least at the level of production (e.g., Cook, 2008; Slabakova, 2013).

EEG/ERP work (in both L1 and L2) focusing on agreement processing in sentence comprehension requires participants to listen to or read sentences with morphosyntactic violations while the neuroeletric activity is being recorded in real time, often asking them to then make a grammaticality judgment after each experimental item. ERP responses, time-locked in the EEG recording to the critical difference between the anomalous item and comparable controls (e.g., *The winner of the big trophy has/*have proud parents*) are compared to see how the brain responds differently when syntactic agreement is not respected. This research is interesting to linguists and acquisitionists in particular, because it appears to provide evidence of qualitatively different brain responses to grammatical versus lexical-semantic violations. Almost all such studies in the monolingual literature—or indeed the native control participants in bilingual studies—report either only a P600 effect (e.g., Alemán Bañón, Fiorentino & Gabriele, 2012;

Hagoort & Brown, 1999; Kolk, Chwilla, Van Herten & Oor, 2003; Nevins, Dillon, Malhotra & Phillips, 2007; Wicha, Moreno & Kutas, 2004), or a biphasic response, involving a Left Anterior Negativity (LAN, 300– 500ms following onset of anomalous word) plus a P600 (e.g., Barber & Carreiras, 2005; O'Rourke & Van Petten, 2011), in comparison to the control sentences. As explained in greater detail in the papers that comprise this volume, the P600 is a positive-going ERP waveform approximately 600ms (between 500-1000mms) following the onset of the critical word and is usually captured by central posterior electrodes of the EEG cap (e.g., Friederici, 2002; Osterhout & Holcomb, 1992). Although the P600 is not a brain response exclusive to syntactic anomalies, the fact that the it reliably emerges in contexts of syntactic agreement violations has motivated the claim that it indexes syntactic repair operations and is thus an indirect correlate to syntactic processing. The LAN has been argued to index automatic morphosyntactic processing (e.g., Friederici, Hahne & Mecklinger, 1996; Molinaro, Barber & Carreiras, 2011; Molinaro, Barber, Caffarra & Carreiras, 2015), however, such an analysis is problematized by the fact that, unlike the P600, it does not consistently obtain. Regardless of why the LAN does not always obtain[ii] in studies of this type, the consistency of the P600 effect makes it relatively uncontroversial to identify the P600 as an indicator of (morpho) syntax-related components. As it relates to second language processing then, any claims of qualitatively similar processing between L1 and L2 speakers will need to show that the P600 obtains in contexts of syntactic agreement violations.

fMRI evidence for language processing

In sharp contrast to the available ERP evidence for grammatical processing in L2 learners and bilinguals, the related fMRI literature remains limited and to a great extent fragmented. fMRI designs tend to differ from ERP ones in several aspects, the most important being that sentences in fMRI experiments are very often presented as a whole, and the brain activation is estimated across the entire sentence, which might have implications in the interpretation of results from certain types of sentences, e.g. those with multiple embeddings or displaced constituents. A recent review (Roncaglia-Denissen & Kotz, 2015) demonstrates that, following on from the ERP literature, a large proportion of the available fMRI studies have focused on the localisation of processing of various types of morphosyntactic and semantic violations. These engage areas such as the left posterior temporal gyrus, which has been suggested to be activated for the processing of complex syntax and of syntactic and semantic violations, as well as for the integration of syntactic and semantic information. Another key area that emerges is the left Inferior Frontal Gyrus (LIFG), with its highly specialised subregions subserving semantic processing and complex syntactic operations such as movement and embedding, as well as modulating the availability of working memory resources for sentence comprehension and production (see Friederici, 2011, for a comprehensive review). In general, the available evidence does not point towards major L1-L2 differences regarding which brain areas such violations engage, at least when proficiency in L2 is high; however, the involved areas tend to activate more or to a greater spatial extent for L2 processing, possibly reflecting increased processing difficulty for non-native speakers (Rüschemeyer, Fiebach, Kempe & Friederici, 2005; Rüschemeyer, Zysset & Friederici, 2006), and similar effects have been reported for late vs. early L2 learners (Hernandez, Hofmann & Kotz, 2007). Notable exceptions to this pattern are studies such as Suh et al., (2007), which show activation of the LIFG for processing of centre-embedded sentences in L1 speakers only, suggesting absence of complex syntactic representations in late L2 learners. These effects are usually attributed to the lack of automatisation of L2 grammatical processing, arguably because the L2 was acquired in adulthood. Such behavior would be expected under some accounts that align with critical period effects for L2 processing, such as the Shallow Structures Hypothesis (e.g. Clahsen & Felser, 2006). Clearly there are differences between child L1 and adult L2 acquisition and processing, however, what underscores L1-L2 developmental, ultimate attainment and processing differences are not definitively known. Assuming a critical period to all domains of language after normal child L1 acquisition is a controversial position (see Rothman 2008 for discussion), so while citing critical period effects is a plausible explanation for the data presented by Suh et al. (2007), it is also possible that high proficiency and/or increased L2 usage overcomes any disadvantages adults seem to have relative to children for later acquisition. For example, Pliatsikas, Johnstone and Marinis (2014a) showed that, similar to native speakers, highly-proficient L2 learners of English process regular past tense inflection via the procedural memory system (Ullman, 2004), including the LIFG, the basal ganglia and the cerebellum, which is assumed not to be available for late L2 processing, due to maturational constraints. Interestingly, the same L2 participants, but not the native speakers, demonstrated a significant positive correlation between the grey matter volume of the cerebellum and their speed in executing a task involving morphological processing (Pliatsikas, Johnstone, & Marinis, 2014b). Pliatsikas and colleagues interpreted this effect as evidence for the proceduralisation of the past tense inflectional rule, providing the first piece of evidence for structural brain changes related to L2 grammatical acquisition. In sum, while there is some neuroimaging research that is beginning to address developmental questions, much more needs to be done.[iii]

Neurolinguistic evidence for grammatical development

In this issue and beyond, Osterhout, Steinhauer, Ullman and Davidson and their colleagues (e.g., Davidson & Indefrey, 2009; 2011; McLaughlin, Tanner, Pitkänen, Frenck-Mestre, Inoue, Valentine & Osterhout, 2010; Morgan-Short, Sanz, Steinhauer & Ullman, 2010), have been investigating longitudinal effects of L2 language development, in contrast to the majority of L2 ERP studies, which are cross-sectional (e.g., Hahne & Friederici, 2001; Friederici, Steinhauer & Pfeifer, 2002; Rossi, Gugler, Friederici & Hahne, 2002). A key and consistent finding across much of the longitudinal research is that there appears to be distinct, *qualitative*, changes in brain signatures that correlate with increased grammatical knowledge. In Osterhout and colleagues' work, for instance, (McLaughlin et al, 2010; Osterhout, McLaughlin, Pitkänen, Frenck-Mestre & Molinaro, 2006) it has been shown that beginning English classroom learners of French display an N400 response to French subject-verb agreement violations, and after a year's classroom instruction, these violations elicit a (more native-like) P600 response. Furthermore, language similarity effects are observed, with native-like responses in evidence earlier in the learning process for agreement phenomena that are comparable between the L1 and the L2 (e.g., Alemán Bañón, Fiorentino & Gabriele, 2014; Frenck-Mestre, Foucart, Carrasco & Herschensohn, 2009; see also, Sabourin & Stowe, 2008).

This work has also focused on the effects of the type of language instruction. Morgan-Short, Steinhauer, Sanz and Ullman (2012) investigated longitudinal learning of an artificial language and found that the extent to which L2 learners came to rely on similar brain mechanisms to those of native speakers was affected by whether the groups had received explicit training (akin to form-focused classroom instruction) or solely implicit input (comparable to immersion contexts). As with the earlier research by Osterhout and colleagues, there was a dissociation between the learners' behavioural performance (in terms of response accuracy in judgment tasks) and their brain signatures across groups of learners, irrespective of type of training or level of proficiency. However, the brain signatures of those who received implicit input and achieved higher proficiency in the new language looked similar to those of native speakers for the processing of grammatical violations: a LAN followed by a P600, whereas an N400 was in evidence in the lower proficiency implicit group, similar to the English learners of French in, for example, McLaughlin et al. (2010). In contrast, explicit training yielded no effects in the lower proficiency explicit group, and an early positivity and a P600 in the more highly proficient group.

One could argue that the N400 component is reflecting the fact that at initial stages, the input is being stored as unanalysed, formulaic chunks, or perhaps probabilistic dependencies are being computed from non-adjacent morphemes (e.g., *Ils*....*V*-ent. cf., McLaughlin et al., 2010) from which generalizable rules are extracted at some later stage (Myles, Hooper & Mitchell, 1998; Tomasello, 2001). This links to the model proposed by Ullman, in which declarative memory subserves explicit knowledge, and procedural memory is responsible for automated computation (Ullman, 2004).

Davidson (this issue; Davidson & Indefrey, 2011) also investigates longitudinal language learning in beginning Dutch L2 learners of German, but charts participants' behavioural responses and brain signatures over the course of one or two experimental sessions. In particular, learners' error- and feedback-related responses to (case/gender/number) agreement violations in German prepositional phrases were analysed in relation to their in/correct performance of grammaticality judgments. No explicit training was given to the participants, but rather they learned via feedback to their correct or incorrect responses throughout the experiment. As with earlier research on agreement violation processing in L2 learners (Sabourin, 2003; Sabourin et al., 2006; Tokowicz & McWhinney, 2005), early on in the training process—and when discrimination between grammatical and ungrammatical items was at chance levels—no P600 effect was observed to the violating adjectives. In general, the P600 component was observed when learning increased[iv], and furthermore, individual variation amongst participants in the amplitude of the P600 was predicted by their accuracy scores (similar to other agreement processing findings reported above, e.g., McLaughlin, et al. 2010). Davidson's research is particularly informative as regards the effects of learners' processing of feedback information when they had made an incorrect choice. Specifically, error-related feedback negativities (150ms-300ms following the feedback response) were observed in greater amplitude at the beginning of learning, decreasing in magnitude as learning improved over time, as measured by discrimination accuracy. That is, initially, the learners, having no knowledge as yet, needed to extract the morphosyntactic information from the feedback response and therefore the feedback itself can be seen to have had much greater impact at early stages of language learning (see also, Holroyd & Coles, 2002).

Taken together, the findings from this work have clear implications for linguistic and language acquisition theories, as well as for classroom practice. These will be discussed in more detail below.

Implications for linguistic and language acquisition theory

Architecture of the linguistic system

ERP findings have featured as part of a number of theoretical accounts of (sentence) comprehension (Batterink & Neville, 2013; Friederici, 2002; 2011; Friederici & Weissenborn, 2007; Hagoort, 2003; Molinaro et al., 2014; Pakulak & Neville, 2010; Ullman, 2004). The fact that there appear to be components specifically related to syntactic processing in contrast to lexical-semantics is clearly of interest to those theoretical linguists who assume the existence of separate linguistic subcomponents. As noted above, syntactic violations consistently elicit P600 effects, but it is not clear exactly what type of process this (or any) component is in fact reflecting. It has been assumed to reflect syntactic integration (Osterhout, Holcomb & Swinney, 1994) and/or reanalysis (Kaan, Harris, Gibson & Holcomb, 2000), although recently, the P600 has also been argued to index thematic or semantic anomalies that are not resolvable (van de Meerendonk, Kolk, Vissers & Chwilla, 2010). In some studies, a biphasic component (a LAN followed by a P600) is observed. What drives early negative-going waveforms (the LAN and the ELAN: an earlier negativity at approximately 100-150 ms) in response to morphosyntactic violations has been under much discussion in the monolingual literature (see, e.g., Steinhauer & Drury, 2012; Tanner, 2015, and footnote ii for discussion and implications of this debate for agreement specifically). In particular, the less often elicited ELAN has been argued to reflect early, automatic syntactic processes that are not amenable to strategic influences, like initial structure-building (e.g., Friederici, 2002; 2011; Friederici & Weissenborn, 2007). However, this component is not reliably in evidence, particularly during reading (Tanner et al., 2012) and could be an artifact of certain materials (e.g., the highly predictable word-category violations between the preposition (*am*) and the prefix of the verb (*ge-*) found in constructions like **Die Bluse wurde am* ***gebügelt*** — 'The blouse was on-the ironed', as discussed by Steinhauer & Drury, 2012). As regards the more commonly but still not consistently found LAN effect, it may be an index of the participants' noticing the syntactic violation: the mismatch between the input and the predicted features based on preceding input (Molinaro Barber, Caffara & Carreiras, 2014; Steinhauser & Drury, 2012), or a combination of prediction and post-lexical integration processes (Kutas, Federmeier & Urbach, 2014). When appearing in isolation, the LAN may be reflective of other types of syntactic processing, such as computation of long-distance dependencies across (multiple) clauses, which by nature require storage in working memory (e.g., Fiebach, Schlesewsky & Friederici, 2002; King & Kutas, 1995).

As well as the issue of the fact that the exact type of knowledge or processing that each component is indexing is far from clear, another important point is extensive individual differences in responses to such grammatical violations even in native speakers (and proficient L2 learners). That is, there appear to be individuals who are more N400-, and some who are more P600-dominant (Tanner et al., 2013; Tanner, Inoue

& Osterhout, 2014). In particular, biphasic responses may be an artefact of averaging over these different sub-groups of participants. For instance, Tanner and Van Hell (2014) review a series of studies on agreement violations and find that such biphasic responses may be caused by some participants showing only (centrally-distributed) N400s, and others no negative response, but rather a P600. As noted by Tanner (2015), this points to a general problem with attempting to interpret components that overlap in ERP studies. That is, it is not at all clear that such components are functionally unique. These differences—evident also in native speakers—suggest that there is more than one route to (syntactic) comprehension (memory-based and computational) and suggest that theoretical linguists and language acquisitionists need to take on board the fact that such neurolinguistic findings may not support their view of linguistic competence. In other words, although there is no specific neurolinguistic evidence to the contrary either, it would be premature to claim that there is an ERP evidence base that maps expressly onto domain-specific syntactic components.

On the other hand, despite findings that areas that serve linguistic functions are also shared with other cognitive domains (Walenski & Ullman, 2005), there is in fact brain imaging evidence that different populations of neurons may be more or less recruited in the service of syntactic versus semantic processing (Hagoort & Indefrey, 2014), as well as some initial evidence for the processing of domain-specific hierarchical syntax (Ding, Melloni, Zhang, Tian & Poeppel, 2015). Key differences appear to lie in the left-posterior inferior frontal gyrus (IFG), a region thought to be involved in non-lexical compositional processes such as sentence comprehension and which might be 'optimised' for L1. Following evidence of reliable activations for the processing of different kinds of demanding sentences (including violations, complex sentences and ambiguities), differences are observed between syntactic and semantic demands with the former driving stronger activation in Brodmann area (BA) 44 than the latter. This is not to say that a strict separation of syntactic and semantic operations should be assumed (as has been the case in earlier research). Rather, this evidence suggests that neuronal populations in this region are *involved* in syntactic computations, or that ‘semantic consequences of syntactic demands (difficulty of thematic role assignment) are processed by neuronal populations that differ from those processing other kinds of semantic unification’ (Hagoort & Indefrey, 2014: 356). Another relevant point is that differences in activation can be found in the posterior temporal lobe between processing violations and other types of demanding sentences; specifically, there is no reliable evidence of activation for processing syntactic or semantic violations. This may be because violations do not necessarily require the retrieval/reappraisal of lexical-semantic and/or semantic information, assumed to be subserved by this area. That is, in violation paradigms, ungrammatical items cannot usually be ‘saved’ by recruiting alternative lexical-semantic information (e.g., *The blouse was on ironed*, Friederici, Rüschemeyer, Hahne & Fiebach, 2003).

The lack of posterior temporal lobe activation in response to syntactic and semantic violations has important implications for our interpretation of the ERP literature on agreement processing, since the majority of these studies use the violation paradigm. Most violation studies require participants to make grammaticality judgments at the end of each experimental item. This is critical to note, since [1] most language processing does not involve encountering such violations, and [2] one could argue that this paradigm taps mainly into *explicit* knowledge, given that participants must consult their metalinguistic knowledge in order to perform the task. Such task effects have been found to influence real-time processing in other studies (see Indefrey, 2006; Roberts, 2013).

Taken together with the observed individual differences in responses to agreement violations noted above, and the fact that those components which are consistently elicited relate to later, less-automatic processes (in contrast to those thought to index more implicit or automatic processes, i.e., (E)LANs), it is unlikely that the above-reported data can tell us anything definitive about linguistic competence or the architecture of the language (sub)systems at this time, and so one cannot arbitrate between modular, generative, and experience-based views of language knowledge and processing.

However, very recent research claims to have provided more ecologically valid and definitive evidence suggesting domain-specificity for language and its central role in language processing. Ding et al. (2015) present magnetoencephalography (MEG) evidence from a series of studies in which participants listened to sentences in both English and Mandarin in which the hierarchical structure between lexical items, larger syntactic phrases/units, and sentences was manipulated, dissociated from intonational speech cues and crucially statistical word cues. The stimuli were of several types and always presented with an equal amount of time between each word: (i) actual and grammatical sentences further subdivided into sentences that were highly predictable (e.g., "Coffee keeps me awake") and those that were less predictable (e.g., "Pink toys hurt girls") and (ii) word lists ("eggs jelly pink awake"). The design allowed the researchers to isolate how the brain tracks in real time different levels of linguistic computation— from lists of words to actual phrases and full sentences. The results show that the brain differentiates in its tracking of the levels of the phrases participants heard, reflecting a hierarchy in neural processing of linguistic structures: words, phrases, and then sentences. Since the brain does this devoid of any additive effects from intonational speech cues and statistical word information that their design removed, one could argue that the data tentatively support the notion of domain-specificity for linguistic hierarchical structure and the brain's predisposition to use these levels of abstraction for real time processing.

Regardless of whether or not neurolinguistic evidence is (yet) able to adjudicate between domain-specific and more experienced-based linguistic approaches to language computation and acquisition, what is clear from the existing evidence base is that neurolinguistic measures can provide reliable indexes that define native-like processing. Such indexes can, in turn, be used comparatively to assess the extent to which non-native processing is at least qualitatively similar or completely distinct in its nature.

L2 syntactic development

Despite the methodological issues noted above, it is clear from the research presented in this issue and elsewhere that qualitative changes in the brain are observed over the course of language acquisition. The ERP research of Osterhout, Steinhauer, Ullman and Davidson shows that, with increased proficiency, responses to morphosyntactic violations appear to become more native-like—in particular, reliable P600 components are observed. Similar findings are also observed in cross-sectional studies, with its being proficiency (and to some extent, L1 background) rather than age of exposure (Hahne &

Friederici, 2001; Friederici, Steinhauer & Pfeifer, 2002; Rossi, Gugler, Friederici & Hahne, 2002) that predicts more native-like P600 effects. Qualitative changes are also reported in neuroimaging studies which have observed hemispheric changes (from right to left) with increased L2 proficiency (Xiang, van Leeuwen, Dediu, Roberts, Norris & Hagoort, 2015; Xiang, Dediu, Roberts, van Oort, Norris & Hagoort, 2012). As has been argued in recent papers by formal linguists studying the acquisition of non-native language adopting neurolinguistic methodologies, the lack of age effects could be said to argue against a critical period for the acquisition of features not shared across the L1 and the L2, and fundamental difference accounts of SLA in general (Alemán Bañón et al., 2012, 2014; Alemán Bañón, Rothman & Miller, 2015; Bond, Gabriele, Fiorentino & Alemán Bañón, 2011; Gabriele, Fiorentino & Alemán Bañón, 2013).

Another major problem, again methodological in nature, in being able to apply the above neurolinguistic findings to theories of SLA is that only a small range of constructions have been tested, using mainly metalinguistic behavioural tasks. There is much debate in the psycholinguistic field on the application of linguistic knowledge during real-time processing, and differences have been observed in processing different types of 'difficult' input (complexities, ambiguities, anomalies; Frazier, 2013; Hagoort & Indefrey, 2014). Thus it is premature to make any theoretical claims on the basis of learners' judgments of agreement violations alone, when other types of knowledge and processes are required to comprehend linguistic input, for instance, for disambiguation and the establishing of long-distance dependencies. Furthermore, recent psycholinguistic research shows different performances depending on experimental task, even with the same speakers. For example, while metalinguistic judgments may be native-like, L2 learners may not be native-like when it comes to more implicit measures (e.g., eyetracking during reading, or self-paced reading, c.f., Roberts, Gullberg & Indefrey, 2008; Roberts & Liszka, 2013).

Although the neurolinguistic evidence which, as a whole, seems to show limited age related effects for the qualitative nature of processing morphosyntax as reflected in brain indexes with EEG (P600) and localization of processing with neuroimaging, these methodologies have not necessarily attempted to tease apart crucial variables that potentially relate to the overall qualitative nature of language processing. For example, Kaan (2014) presents a thorough review of the L2 processing literature with an eye towards addressing the question of whether or not natives and non-natives are able to anticipate or calculate expectations similarly. The evidence is, overall, inconclusive as to whether or not—and if so why—a crucial difference between native and non-native speakers is their ability to use linguistic cues predictively. Grüter, Rohde and Schafer (in press) offer the Reduced Ability to Generate Expectations (RAGE) hypothesis, which states that in general L2 learners have less than optimal abilities to use cues in real-time input to generate predictions. As follows from RAGE, it might not be the case that L2ers suffer from any maturationally conditioned inability to acquire new morphosyntactic representations, which would be in line with the evidence presented by the papers in the special issue, but rather that differences in how they can use language-specific linguistic cues to process qualitatively like native speakers might be at the heart of so-called L1-L2 differences. Future neurolinguistic research that uses indexes related to expectation-driven processing—e.g., the N400 as an index of expectation—specifically designed to weigh in on this question is welcomed.

Despite recent advances and the opportunity for future research that can offer more tangible conclusions, just as the current evidence cannot arbitrate between different accounts within the same theoretical framework, it also cannot as yet inform the debate between SLA theories (e.g., generative versus emergentism), particularly given that there is no reliable neurophysiological index of automatic knowledge or processing that can tell us, for instance, what may be implicit or explicit knowledge.

Implications for Language Instruction

The neurolinguistic findings in this special issue, together with those from other research, have interesting applications for language teaching. This is particularly the case because almost all of these studies involve instructed learners. In particular, learners appear to be able to learn from feedback, even if not explicitly taught (Davidson, this issue; Davidson & Indefrey, 2011). In fact, although immersion is optimal (Morgan-Short, et. al, 2010) learners do benefit from explicit instruction (Davidson & Indefrey, 2009; McLaughlin et al., 2010). Grammatical learning appears also to be in evidence in extremely short periods of time, even over the duration of one or two experimental sessions, and within a year of classroom instruction, learners can show native-like knowledge and processing, even—albeit at a slower rate—for constructions that differ between the L1 and the L2 (McLaughlin et al., 2010).

For researchers that have argued for an interface—to some degree—between language instruction and eventual language competence, in the sense that declarative knowledge can become proceduralised, neurolinguistic evidence suggesting benefits of feedback will come as no surprise. Theories of second language acquisition that subscribe to formal linguistic theory have tended to lag behind in terms of imagining that instruction can play any role in affecting actual grammatical representation. Since as far back as Krashen's distinction between learning and acquisition in the 1970s, SLA research in the Chomskyian tradition has largely assumed that negative evidence cannot evoke changes in linguistic systems of competence, although it might very well affect metalinguistic representations and thus potentially production. It is not clear from any of this evidence that feedback or explicit instruction actually affects underlying representation within the linguistic grammar, after all even if passing to proceduralised storage, explicit knowledge can still be very different from knowledge that is truly implicit from its inception. We do know, however, based on some neurolinguistic research, that there can be a positive effect of instruction on how language is processed and potentially the rate at which language is learned, if not truly acquired. This information couples nicely then with recent attempts in the Chomskyan tradition of studying SLA that attempt to stimulate better connections with language teaching (e.g., Whong, 2011; Whong et. al., 2013). At a minimum, it seems to point out that metalinguistic awareness and focusing on form can induce changes that are measurable in the brain, both functional and structural, that is, in complement to what is seen behaviourally in performance and sometimes revealing knowledge that is otherwise obscured in real time performance. Neurolinguistic studies, as is true of formal linguistic studies, that wish to have true pedagogical impact will be designed to help figure out what parts of language are best served by metalinguistic training. In turn, this will help teachers to use time resources better and construct bespoke pedagogies that maximize what is known about language, its acquisition and its neurological underpinnings to promote the most effective learning scenarios. It is beyond our expertise to discuss how this will be undertaken in practical terms, however, this is taken up in Restelli's commentary in this issue.

Conclusions

With the benefit of insights provided by the abundant research undertaken over the past two decades, we are beginning to uncover the neurocognitive underpinnings of linguistic knowledge, processing and acquisition. However, the methodological problems described above compromise our ability to promote mutually informed scientific progress between neurolinguistic work, on one side, and linguistic and language acquisition theories on the other. In order to overcome these confounds, a number of issues will need to be addressed. Firstly, before we can tackle the fundamental question of whether or not neurological findings can arbitrate between different L2 theories, we need a clearer picture of what aspects of linguistic competence are being indirectly tapped through the processing indexes provided by neurolinguistic tools. Our understanding of these indexes will only be improved by inspecting a wider range of construction types, using different sets of tasks—for instance, comprehension without metalinguistic judgments—comparing production with comprehension data, etc. Language learning and processing in different contexts is also important. As Green notes (this issue), different patterns of bilingual use (for instance, code-switching) can lead to different ways of constructing effective turn-taking in natural conversation as mediated by cognitive control. He takes a 'behavioural ecological perspective' and this is clearly an approach that will be highly interesting in the future. In particular, great benefits can be gained across all disciplines (linguistics, neurolinguistics, pedagogy) with more dialogue between researchers, as evaluating data from different approaches forces us to examine critically our own theories and methods, and this can only bring a deeper understanding of the nature of language and language acquisition, and in turn, better inform language instruction.

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[i] Many studies undertaken by psychologists refer to all L2 learners as *bilinguals*.

[ii] It might be the case that the bi-phasic LAN reported in these studies is a methodological artefact and is actually related to a possible N400 that is being inadvertently hidden (Guajardo and Wicha, 2014; Osterhout and Nicol, 1999; Service, Helenius, Maury, Salmelin, 2007; Tanner and Van Hell, 2014). The N400 (Kutas and Hillyard, 1980; Kutas & Federmeier, 2011), usually attributed to lexical-semantic processing, is a negative going wave which exhibits similar polarity and latency to the LAN, but whose scalp distribution is very similar to the P600. Given the overlap in scalp distribution between the P600 and the N400 and the ensuing effects on latency, their potential co-existence may cause the N400 to emerge in the left anterior portion of the scalp, creating the illusion of a LAN (but see Molinaro et al., 2015). The presence of the N400 for agreement errors may reflect individual processing strategy differences (e.g., Tanner and Van Hell, 2014) or difficulty with semantic integration depending on the constraining context of the agreement error (e.g., Guajardo and Wicha, 2014). For example, outside of sentential syntactic contexts—when agreement is presented within an agreement phrase in isolation (Barber & Carreiras, 2005)—lexical semantics might be more engaged, producing what seems to be a LAN. This will be expanded and discussed more globally—for processing of syntax more generally—in sections below.

[iii] As a reviewer points out, developmental neurolinguists may well benefit from the neurological research on (the development of) consciousness (Baars, 1988; Dehaene and colleagues, e.g., Del Cul A., Baillet S., & Dehaene, 2007).

[iv] Similarly to Davidson and Indefrey (2009), this violation response was only evident in four-word constructions, in which the violating adjective carried redundant features (e.g., mit dem[+DAT, -F, -M] *kleinem[+DAT, -F, -M] Kind, '*with the small child'*) and not to items in which the anomalous adjective was *default,* i.e., not specified for syntactic features (e.g., mit *kleinen[] Kind). These findings are in support of the hierarchical feature specification paradigm of German adjectives (e.g., Schlenker, 1999; see Clahsen, et al., 1999, for psycholinguistic evidence).