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Native-like brain processing of syntax can be attained by university foreign language learners

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ABSTRACT

Using event-related potentials (ERPs), we examined the neurocognition of late-learned second language (L2) Spanish in two groups of typical university foreign-language learners (as compared to native (L1) speakers): one group with only one year of college classroom experience, and low-intermediate proficiency (L2 Low), and another group with over three years of college classroom experience as well as 1–2 semesters of immersion experience abroad, and advanced proficiency (L2 Advanced). Semantic violations elicited N400s in all three groups, whereas syntactic word-order violations elicited LAN/P600 responses in the L1 and L2 Advanced groups, but not the L2 Low group. Indeed, the LAN and P600 responses were statistically indistinguishable between the L1 and L2 Advanced groups. The results support and extend previous findings. Consistent with previous research, the results suggest that L2 semantic processing always depends on L1-like neurocognitive mechanisms, whereas L2 syntactic processing initially differs from L1, but can shift to native-like processes with sufficient proficiency or exposure, and perhaps with immersion experience in particular. The findings further demonstrate that substantial native-like brain processing of syntax can be achieved even by typical university foreign-language learners.

1. Introduction

Recent years have witnessed a blossoming of research on the neurocognitive mechanisms underlying late-acquired second language (L2) (for reviews, see Abutalebi, 2008; Clahsen, Felser, Neubauer, Sato, & Silva, 2010; de Groot, 2011; Doughty & Long, 2005; Green, 2003; Hernandez & Li, 2007; Indefrey, 2006; Kotz, 2009; Kroll & de Groot, 2005; Gass & Mackey, 2012; Morgan-Short & Ullman, 2011; Paradis, 2009; Schmidt & Roberts, 2009; Steinhauer, White, & Drury, 2009; Ullman, 2005). Much of this work has investigated whether the neurocognition of L2 differs from or is similar to that of first (native) language (L1). However, this research program has by no means yielded definitive conclusions, and many open questions remain.

Three competing theoretical perspectives have addressed the neurocognitive relationship between L2 and L1. First, some researchers have hypothesized that the mechanisms underlying L2 are essentially the same as those subserving (fully-acquired) L1 (Abutalebi, 2008; Ellis, 2005; Hernandez, Li, & MacWhinney, 2005; Indefrey, 2006; MacWhinney, 2012). Second, others have proposed that the mechanisms underlying L2 are fundamentally different from those of L1 (Bley-Vroman, 1989).

A third group of theories hypothesize that L2 learners initially depend heavily on different substrates than L1, but, with increasing experience or proficiency, gradually rely more on L1 neurocognitive mechanisms (Clahsen & Felser, 2006a; Paradis, 1994; Ullman, 2001). The nature of this shift differs among the particular theories. Paradis (1994, 2004, 2009) suggests that a shift between neurocognitive systems can take place both for rule-governed grammatical processes, and at least some lexical properties, specifically, grammatical properties of lexical items that are generally implicit in L1. On the views of Ullman and Clahsen, lexical/semantics relies on the same set of neurocognitive mechanisms in L2 and L1, whereas grammar shows a more complex relationship (Clahsen & Felser, 2006a, 2006b; Clahsen et al., 2010; Ullman, 2001, 2005, 2006, 2012). In particular, both Ullman and Clahsen hypothesize that aspects of rule-governed grammar are predicted to depend on different mechanisms at earlier versus later stages of L2 acquisition, corresponding to lower and higher levels of proficiency and/or experience. At lower levels, these aspects of

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grammar are thought to rely largely on lexical/semantic processes that do not normally play a primary role in grammar in adult L1. The exact nature of these lexical/semantic processes is unclear (and differs somewhat between Clahsen and Ullman), but may include chunking (memorizing complex forms, such as "walked" or the "the cat"), associative generalization in lexical memory, semantic-based parsing, and explicit rules. In addition, Ullman specifically ties these lexical/semantic processes to the declarative memory brain system. Crucially however, as proficiency and/or experience increase, L2 grammar is expected to rely less and less on these processes and more and more on mechanisms that normally underlie grammar in L1 (which Ullman ties to the procedural memory brain system). For Ullman, most or all aspects of grammar can potentially become native-like. For Clahsen, such native-like processing is typically restricted to local dependencies, and native-like processing of nonlocal dependencies and "complex syntax" are not generally expected (Clahsen & Felser, 2006a, 2006b). Thus, both Clahsen and Ullman predict that the neurocognition of lexical/semantics should be qualitatively the same in L2 and L1, at all proficiency and experience levels, whereas rule-governed aspects of grammar should rely largely on lexical/semantics at lower levels, but at least to some extent on native-like aspects of grammatical processing at higher levels – though the exact time course of this shift and for what aspects of grammar this shift may occur remains unclear, largely due to a lack of relevant empirical evidence. In this study, we investigate the time course and nature of this shift within the context of typical university-level language study in the U.S.

1.1. Event-related potentials

Event-related potentials (ERPs) may be one of the best methods for teasing apart these competing theories, and more generally for elucidating the neurocognitive relationship between L2 and L1. ERPs reflect real-time scalp-recorded electrophysiological brain activity of cognitive processes that are time-locked to the presentation of target stimuli. Unlike hemodynamic imaging methods like fMRI, ERPs provide excellent temporal resolution, allowing one to examine the actual time course of processing. Additionally, ERP research has revealed a set of widely-studied language-related activation patterns ("ERP components") in L1, whose characteristics and underlying functions are reasonably well understood (see below). Moreover, lexical/semantic and (morpho)syntactic processing in L1 are associated with largely distinct ERP components. These components thus provide a reasonably clear method of comparing the neurocognition of language processing between L2 and L1, in particular for lexical/semantic and (morpho)syntactic processing. Importantly, since ERPs can be sensitive to effects not observed with behavioral measures, including in language learning studies (McLaughlin, Osterhout, & Kim, 2004; Tokowicz & MacWhinney, 2005), they can potentially reveal L2–L1 differences and similarities that might not be found with purely behavioral approaches.

In L1, ERP studies have shown that lexical/semantic difficulties (e.g., "That train has very large *macaroni", where * indicates a violation or anomaly), which are examined in the present study, consistently elicit "N400" components. These are central/posterior bilaterally distributed negativities that generally occur about 300–500 ms after the onset of the stimulus. They are associated with lexical/semantic processing (Kutas & Federmeier, 2010; Kutas & Hillyard, 1980; Steinhauer & Connolly, 2008), and have been linked to the declarative memory brain system (Nobre, Allison, & McCarthy, 1994; Simos, Basile, & Papanicolaou, 1997; Ullman, 2004). More specifically, it has been suggested that, at least in language processing, the N400 may reflect aspects of lexical access and the postlexical integration of word meanings into episodic memory (Kutas & Federmeier, 2000).

In contrast, disruptions of rule-governed (morpho)syntactic processing in L1, such as word-order (phrase structure) violations (e.g., "The man hoped to *meal the enjoy with friends"), which are also examined in the present study, often produce three components. First, such difficulties sometimes, but not always (Hagoort & Brown, 1999; Osterhout, Bersick, & McLaughlin, 1997), elicit early (about 100–500 ms) left-distributed and/or anterior negativities ("LANs"; we emphasize that even in L1, such negativities may be left-lateralized, anterior, or both; these distributional differences are not yet well understood) (Friederici, Pfeifer, & Hahne, 1993; Neville, Nicol, Barss, Forster, & Garrett, 1991; Pakulak & Neville, 2010). It is not yet clear whether the earlier-onset LAN (often called an "ELAN", which can begin as early as around 100 ms), and the LAN that occurs somewhat later (usually beginning around 300 ms), reflect the same or different components. Indeed, it has been argued that the presence of ELANs in the majority of previous studies that report them may in fact be due to artifacts caused by baseline problems from differences in the material preceding the target word (Steinhauer & Drury, 2012) – a problem that is avoided in the design of the present study. For simplicity, here we use the term LAN to refer to both earlier and later LAN effects. Although the exact nature of the processing mechanisms underlying LAN effects remain to be elucidated, evidence suggests that they may reflect aspects of rule-governed automatic structure-building (Friederici & Kotz, 2003; Hahne & Friederici, 1999; Hasting & Kotz, 2008; Steinhauer & Connolly, 2008; Steinhauer & Drury, 2012; van den Brink & Hagoort, 2004) and they may depend on the procedural brain system (Hoen & Dominey, 2000; Ullman, 2004). In an influential account of language processing (Friederici, 1995, 2002; Friederici & Kotz, 2003) early LAN effects have been argued to reflect first-parse structure building, while the later LAN effects have been interpreted as reflecting morpho-syntactic processing.

Second, (morpho)syntactic disruptions in L1 also usually elicit – and indeed, more reliably than LAN effects – late centro-parietal positivities (P600s, often beginning around 600 ms). The P600 has been linked to controlled (conscious) processing, syntactic integration, and structural reanalysis (Friederici & Kotz, 2003; Hahne & Friederici, 1999; Kaan, Harris, Gibson, & Holcomb, 2000; Osterhout & Holcomb, 1992; Steinhauer & Connolly, 2008). It remains unclear whether or not the P600 is language specific, and some evidence suggests that this component may be part of the larger P300 family, or might comprise P300 subcomponents (Steinhauer & Connolly, 2008).

Third, (morpho)syntactic disruptions have also often been found to elicit later sustained anterior negativities ("late anterior negativities"; these may start as early as 500 or 600 ms, though they are often more prevalent in later time windows) (Friederici et al., 1993; Gillon Dowens, Vergara, Barber, & Carreiras, 2010; Martin-Loeches, Munoz, Casado, Melcon, & Fernandez-Frias, 2005; Pakulak & Neville, 2010). It has been suggested that such later negativities, which have recently begun to receive more attention, may represent a continuation of the LAN (or similar processes to the LAN) (Pakulak & Neville, 2010; Steinhauer & Drury, 2012), or alternatively, that they may reflect something other than automatic structure-building, such as processes related to increased working memory demands (Martin-Loeches et al., 2005; Sabourin & Stowe, 2008; Vos, Gunter, Kolk, & Mulder, 2001).

1.2. ERPs in second language

As in L1, in late-learned L2 (here we discuss studies in which the mean age of acquisition is at least 10 years) difficulties in lexical/semantic processing reliably yield an N400, though in many cases this component is delayed or reduced in amplitude