

Individual variation in syntactic processing in the second language:

Electrophysiological approaches

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Abstract

This chapter reviews research on how individual differences in linguistic and cognitive abilities influence syntactic processing in the second language (L2). We briefly discuss individual variability in L2 syntactic processing through the lens of behavioral measurements, followed by a more extensive review of electrophysiological (i.e., Event-Related Potentials, ERP) studies on L2 syntactic processing. Relative to the behavioral literature, fewer ERP studies have examined individual variability in L2 syntactic processing and the large majority of these studies focused on only two factors: Age of Acquisition and L2 proficiency. We also discuss studies that used correlational and regression analyses and oscillatory neural dynamics and complex network analysis. We conclude the chapter with a discussion of studies that examined inter-individual variation in ERP response profiles associated with L2 and L1 syntactic processing in L2 learners, and the application of the Response-Dominance Index to quantify individual variability in ERP response profiles.

Keywords:

Second Language Processing, Syntactic Processing, Individual Differences, Electrophysiology, Event-Related Potentials, Neurocognition, Psycholinguistics

In past decades, research on syntactic processing has provided important insights into the linguistic and cognitive factors that contribute to individual differences in syntactic processing (for reviews, see Dabrowska, 2012; Farmer, Misyak, & Christiansen, 2012; Roberts, 2012). This chapter focuses on individual differences in one specific group of language users, adults who process sentences in their second language (L2). We will first briefly discuss individual differences in L2 syntactic processing through the lens of behavioral measurements. In the main part, we will discuss neurocognitive studies on individual differences in L2 syntactic processing. We specifically focus on electrophysiological studies. As will become clear, relative to the behavioral literature, fewer electrophysiological studies examined individual differences in second language syntactic processing, and the large majority of these studies focused on only two factors: Age of Acquisition (AoA) and L2 proficiency.

Individual Differences in Second Language Syntactic Processing:

Electrophysiological Studies

A large body of research using behavioral methodologies has shown that individuals tend to differ greatly in the rate and success of L2 language development, and the ultimate attainment of native-like language processing in L2 learners (for a recent review, see Dörnyei & Ryan, 2015). This research also includes studies on L2 syntactic processing. Individual difference factors that have been found to affect L2 syntactic processing include working memory (e.g., Juffs & Harrington, 2011; Linck, Osthus, Koeth, & Bunting, 2014), executive function abilities (e.g., Kapa & Colombo, 2014), AoA (e.g., Birdsong, 2006; Johnson & Newport, 1989), language proficiency

(e.g., Hopp, 2015), aptitude (e.g., Robinson, 2005) learning styles (e.g., Grey, Williams, & Rebuschat, 2015), motivation (e.g., Allen, 2010), and personality (e.g., Dewaele, 2005; Grey et al., 2015).

The wealth of studies that examined individual variation in L2 syntactic processing using behavioral measurements stands in marked contrast to the relatively low number of studies that examined individual differences in L2 syntactic processing using electrophysiological measures. Moreover, the available electrophysiological evidence is largely constrained to the role of AoA and L2 proficiency in L2 syntactic processing. Before discussing selected studies on L2 syntactic processing in more detail, we will briefly discuss electrophysiological methodology, and how this methodology is used in research on syntactic processing.

EEG and ERP methodology

Electroencephalography (EEG) is an electrophysiological monitoring method to record electrical activity in the brain over time, measured at the scalp. Event-Related Potentials (ERPs) are derived from the EEG, and reflect regularities in electrical brain activity that are time-locked to the onset of an external event, such as hearing or reading a word (for an excellent introduction to ERP recording and analysis, see, Luck, 2014). ERPs provide a millisecond-by-millisecond record of the brain's electrical activity during mental processing as it unfolds over time, and this method has been widely used in research studying L1 and L2 sentence processing. The large majority of these studies have used a violation paradigm, comparing the visual or auditory processing of sentences containing a violation of a specific syntactic rule or principle (subject-verb agreement, as in **The man walk on the beach*) with processing

of a correct sentence. The two main types of syntactic violations that have been examined are morphosyntactic violations (e.g., violations of number, gender, case, or person agreement, and tense-marking violations) and phrase-structure violations (e.g., violations of word order, word category, or word omissions); for reviews, see Caffarra, Molinaro, Davidson, and Carreiras (2015), Morgan-Short, 2014; Steinhauer, White, and Drury (2009), and Van Hell and Tokowicz (2010). ERPs are time-locked to the presentation of the critical word signifying the violation. For example, in the sentence **The man walk on the beach*, the critical word is ‘walk’, because this is the earliest point at which participants could detect the violation.

A typical ERP signal consists of a series of positive and negative peaks related to stimulus processing. These ERP components are characterized by polarity, latency, amplitude, topographic scalp distribution, and a functional description of the cognitive processes they are assumed to index. The main components associated with L1 and L2 sentence processing are the Early-Left Anterior Negativity (ELAN), the Left Anterior Negativity (LAN), the N400, and the P600. The ELAN is an anterior negativity that occurs in the 150-250 ms latency range, is often lateralized over the left hemisphere, and is assumed to reflect automatic early syntactic parsing and building up an initial phrase structure (e.g., Hahne & Friederici, 1999). The LAN is also an anterior negativity that is often left-lateralized, but it occurs slightly later, in the 300-500 ms range, and is assumed to index the integration of morphosyntactic information in a sentence structure; the LAN correlates particularly with morphosyntactic violations (e.g., Friederici, 2002; Molinaro, Barber, & Carreiras, 2011; cf., Tanner & Van Hell, 2014). The N400 is a large-amplitude, negative-going wave beginning about 300 ms post-stimulus and reaching its maximum around 400 ms post-stimulus. Although the N400 occurs in the same time window as the LAN,

the N400 is usually largest over central and parietal electrode sites. The N400 is considered to index the integration of meaning and world knowledge, which depends on, for example, the strength of the semantic relation between the target word and the preceding sentence (e.g., DeLong, Urbach, & Kutas, 2005; Hagoort, Hald, Bastiaansen, & Petersson, 2004; Kutas & Hillyard, 1980). In L2 learners, N400 effects have also been found in morphosyntactic violations (e.g., Osterhout et al., 2006). The P600 is a positive-going wave that appears around 500-600 ms post-stimulus and extends for several hundred milliseconds, and has a broad posterior scalp distribution that is greatest over centro-parietal regions (e.g., Friederici, 2002; Osterhout & Holcomb, 1992). The P600 is considered to index syntactic reanalysis and repair following the detection of a syntactic violation (e.g., Osterhout & Holcomb, 1992) or processing syntactically-complex structures (Kaan, Harris, Gibson, & Holcomb, 2000), as well as monitoring, checking, and reprocessing of information (e.g., Kolk & Chwilla, 2007).

As mentioned above, EEG/ERP studies on individual differences in L2 syntactic processing mainly focused on two factors, AoA and L2 proficiency, and treated individual difference measures as categorical variables (see also Van Hell & Tanner, 2012). We will review these studies below. We will also discuss studies that used more advanced EEG/ERP analyses to study individual differences in syntactic processing.

Age of Acquisition

The age at which L2 speakers acquired their second language is the most frequently studied individual differences factor in the L2 sentence processing literature

(Birdsong, 2006; Van Hell & Tokowicz, 2012). Studies focusing on AoA often tested the critical period hypothesis, which states that there is a time window early in life during which the brain is especially sensitive to learning. This early window is either considered critical and defined by maturational constraints that prohibit late (post-puberty) learners of an L2 to attain native-like proficiency (critical period hypothesis), or is considered to be merely facilitatory (sensitive period variant of this hypothesis; See Birdsong, 2006, for a more elaborate discussion of the two variants). The latter interpretation comes closer to the assumption of an age-related decline in L2 acquisition that is not due to a particular period of brain development. Instead, this view emphasizes a linear decline in ultimate attainment with increased age of first exposure to the L2 that is attributable to decline in general cognitive mechanisms.

In a classical study, Weber-Fox and Neville (1996) examined Chinese-English bilinguals living in the United States who were first exposed to English at different ages (corresponding to the age they emigrated to the United States). Participants read sentences containing two critical types of syntactic violations: phrase structure (e.g., **The scientist criticized Max's of proof the theorem*) and specificity constraint (e.g., **What did the scientist criticize Max's proof of?*). Weber-Fox and Neville (1996) found that the ERP correlates of all L2 learners, irrespective of age of first exposure to English, differed from those of native speakers, but these differences were most pronounced in the late L2 learners (AoA 11 years or higher). More specifically, in native speakers, phrase structure violations elicited an early left-lateralized anterior negativity, followed by a later left-lateralized negativity over temporal and parietal sites between 300-500 ms, and a broadly-distributed late positive shift (P600). By contrast, none of the L2 learners showed the early left-lateralized negativity. L2 learners did show the later negativity between 300-500 ms (which was bilaterally

distributed for the L2 learners exposed to English at age 11 or later), but only the earlier L2 learners (AoA before 11 years), and not the late L2 learners, showed a typical P600. For the specificity constraint violations, ERP responses of the earlier L2 learners (AoA before 11 years) were comparable to those of the native speakers, but different from the ERP signatures of the late L2 learners (AoA after 11 years). Together these data indicate that AoA impacted ERP signatures associated with syntactic violations. Weber-Fox and Neville (1996) concluded that maturational changes constrain the neural systems that are relevant for language learning and processing, and that puberty marks a significant point in development for language learning capacity.

However, the bilinguals tested in Weber-Fox and Neville (1996) not only differed in age of first exposure to English, but also in life-long exposure to L2 English (17.9 and 7.6 years of overall exposure for learners with AoA between 1-3 years and > 16 years, respectively), as well as L2 proficiency. Because of this confound, the observed differences between age groups cannot be unequivocally attributed to AoA. In a later study, Pakulak and Neville (2011) addressed this issue and disentangled AoA and L2 proficiency by comparing syntactic processing of late L2 English learners matched for grammatical proficiency in English with a group of lower proficiency English native speakers. Participants listened to sentences that contained phrase structure violation (e.g., **Timmy can ride the horse at my his farm*) and the correct equivalents while ERPs were recorded. In the native speakers, violations elicited a bilateral and prolonged anterior negativity with onset at 100 ms, followed by a P600. In contrast, in L2 speakers the violations did not elicit an anterior negativity, but only a P600 which was more widespread spatially (extending to more anterior sites) and temporally (extending to 1200 ms post-stimulus) than in the native

speakers. A similar pattern of findings was reported by Hahne (2001), testing phrase structure violations in late but proficient L2 German speakers. According to Pakulak and Neville (2011), these findings indicate that both early and late syntactic processes are sensitive to maturational constraints, and corroborate the findings in Weber-Fox and Neville (1996) that even highly proficient L2 speakers rely on different neural mechanisms during syntactic processing than native speakers do.

In a recent study, Meulman, Wieling, Sprenger, Stowe, and Schmid (2015) adopted a different approach to study AoA effects in L2 syntactic processing. Rather than dividing bilinguals into different categories on the basis of their AoA, Meulman et al. used general additive modeling (GAM), treating age as a continuous variable and studying the (non-linear) ERP pattern over time to examine potential latency effects (e.g., Tremblay & Newman, 2014). Slavic L1 speakers (Polish and Russian) with advanced proficiency in L2 German, but a wide range of AoA in German, listened to grammatically correct and incorrect sentences containing violations of non-finite verbs and grammatical gender agreement. Non-finite verbs have shown to be relatively easy for these learners to acquire because of structural similarities between the bilinguals' L1 and L2, but grammatical gender agreement is notoriously difficult, even for highly proficient Polish and Russian late learners of L2 German. Verb agreement violations elicited a P600 in native speakers and in all bilinguals, irrespective of their AoA. Gender agreement violations elicited a P600 in bilinguals with an AoA up to 20 years, whereas bilinguals with a higher AoA showed a posterior negativity in this time window. Moreover, the GAM analysis revealed that AoA effects were linear, and did not show any evidence of a discontinuity, which argues against the presence of a critical period.

L2 Proficiency

A growing body of research has studied how individual variation in L2 proficiency affects ERP signatures associated with syntactic processing in L2. This research has adopted different approaches: 1) a comparison of different groups of L2 learners who varied in L2 proficiency, 2) longitudinal studies of L2 learners who typically learned their L2 in a classroom setting, 3) lab-based teaching of an artificial language or a miniature language that enables studying longer-term language learning within a short timeframe.

Studies comparing different L2 learner groups who vary on L2 proficiency

Studies comparing different L2 learner groups typically compare less proficient learners with more proficient learners (e.g., Diaz et al., 2016; Rossi, Gugler, Friederici, & Hahne, 2006; Tanner, McLaughlin, Herschensohn, & Osterhout, 2013), and in some studies these groups were matched on AoA (e.g., Bowden, Steinhauer, Sanz, & Ullman, 2013; Ojima, Nakata, & Kakigi, 2005). Particularly studies adopting the latter approach provide insight into the role of L2 proficiency on syntactic processing, irrespective of AoA. For example, Ojima et al. (2005) tested native English speakers and native Japanese speakers who began to learn English in Japan between ages 10-12, and who attained either intermediate or high proficiency as assessed by an independent formal test and self-ratings of proficiency. Participants read sentences that contained subject-verb agreement violations in L2 English and corresponding correct counterparts. Ojima et al. found that subject-verb agreement violations elicited an enhanced left-lateralized negativity between 350-550 ms in native speakers and in highly-proficient L2 learners, but not in moderately-proficient

L2 learners. This LAN was followed by a P600 in the native speakers, but not in either group of learners. Native speakers thus showed a biphasic LAN-P600 pattern, highly-proficient learners showed a LAN but no P600, and moderately-proficient learners showed none of the ERP components typically associated with syntactic processing.

More recently, Bowden et al. (2013) tested English-Spanish bilinguals who had been first exposed to Spanish in a classroom environment, at around the same age (between 12-14 years). The low L2 Spanish proficiency group had one year of college classroom experience, and the advanced L2 Spanish proficiency group had over three years of classroom experience and 1-2 semesters of immersion experience abroad. Word-order violations (reversing the positions of nouns and verbs) elicited a LAN and a P600 in the native Spanish speakers and the advanced L2 learners, but not in the low-intermediate L2 learners who showed a left anterior to centro-anterior positivity and a centro-posterior to posterior positivity in these time windows.

Together these studies show that L2 proficiency modulates the ERP signatures associated with L2 syntactic processing, with high proficiency L2 learners often displaying patterns coming close that those of native speakers, whereas the ERP responses of low-proficiency L2 learners display quantitative and qualitative differences.

Longitudinal studies of L2 learners who develop L2 proficiency over time

A second approach recently adopted to examine the role of L2 proficiency on L2 syntactic processing is that of longitudinal studies of L2 learning in which neurocognitive changes associated with L2 syntactic processing are tracked over time (see Osterhout et al., 2006, for a detailed discussion of such designs). Osterhout et al.

(2006) tracked native English speakers in their first year of university French instruction. The learners, tested after 1, 4, and 8 months of instruction, were presented with sentences that contained two types of grammatical violations: subject-verb (person) agreement which is phonologically realized in French, and determiner number agreement which is not phonologically realized and differs in French and English. Native French speakers demonstrated a P600 in response to both kinds of syntactic violations. A different pattern was observed in the L2 learners, which changed throughout the course of L2 learning. After one month of instruction, the French L2 learners were not sensitive to violations of determiner number agreement, and demonstrated an N400 in response to the subject-verb agreement violations. This suggests that the latter violations were treated as lexical-level violations, and reflect lexical-level processing rather than rule-based knowledge (see Guo, Guo, Yan, Jiang, and Peng (2009), Tanner et al. (2013), and Tanner, Inoue, and Osterhout (2014) who also observed N400 effects in novice L2 learners). After four months of instruction, the French L2 learners demonstrated a P600 in response to the subject-verb agreement violations. However, even after eight months of L2 learning they still did not demonstrate reliable sensitivity to the determiner number agreement violations.

McLaughlin et al. (2010) described a series of longitudinal studies that track L2 learners' development of different L2 morphosyntactic structures over the course of a beginning one-year university-level course. Learners quite consistently demonstrated a shift from N400 effects in the early stage of L2 learning to P600 effects at a later stage in learning, indicating qualitative shifts from N400 to P600 effects with increased L2 exposure and proficiency.

Qualitative changes in ERP signatures in the course of L2 learning were also observed by White, Genesee, and Steinhauer (2012) who tested Chinese and Korean

late-L2 learners of English at the beginning and end of a 9-week intensive English as L2 course. The L2 learners were presented with sentences containing violations of regular past tense, a structure that does not exist in Chinese and operates differently in Korean, and their correct counterparts. Although no P600 effects were present at the beginning of L2 instruction, both L2 learner groups displayed P600 effects by the end of the L2 course. In contrast to Osterhout et al. (2006), no N400 effects were observed in the early stage of L2 instruction. Finally, in a short one-session training study, Davidson and Indefrey (2009) found that Dutch learners of L2 German who had not demonstrated sensitivity to adjective declension violations and gender agreement violations prior to the one-session training displayed a P600 in response to declension violations at the end of training, but not to gender agreement violations.

Learning of artificial languages to track changes in proficiency within short timeframe.

A third approach in which the role of L2 proficiency can be systematically studied is via artificial languages or miniature natural languages (e.g., Batterink & Neville, 2013; Friederici, Steinhauer, & Pfeifer, 2002; Mueller, Hahne, Fujii, & Friederici, 2005). One advantage of this approach is that learners can become highly proficient in a relatively short amount of time, and proficiency levels can be explicitly manipulated while keeping time of first exposure identical. Using this approach, Friederici et al. (2002) taught native German speakers a miniature artificial language called Brocanto. The experimental group was extensively trained on Brocanto and became highly proficient. The control group was given only vocabulary training to isolate the effects of syntactic knowledge. During testing, learners heard sentences with or without syntactic word category violations. The experimental group showed a bilateral early

anterior negativity followed by a P600, whereas the control group showed neither, indicating learning based shifts in processing. Furthermore, a subsequent analysis focusing only on Brocanto rules that could not have been transferred from L1 German revealed that the finding of biphasic syntactic sensitivity was due to learning and not L1 transfer.

Combining the benefits of teaching learners an artificial language and a longitudinal research design, Morgan-Short and her colleagues (Morgan-Short, Sanz, Steinhauer, & Ullman, 2010; Morgan-Short, Steinhauer, Sanz, & Ullman, 2012) taught adults Brocanto2, a modified version of Brocanto whose syntactic rules conform to natural-language universals. Learners received either explicit training (metalinguistic explanation and meaningful examples) or implicit training (only meaningful examples). ERP responses to sentences containing morphosyntactic violations (noun-adjective and determiner-noun gender agreement violations) and syntactic violations (word order violations) were collected after the first training session and at the end of the three-session training. At lower levels of proficiency, both morphosyntactic and syntactic violations elicited an N400 in the implicit group, but no significant ERP response in the explicit group. At higher levels of proficiency, morphosyntactic violations elicited an N400 followed by a P600 in both groups, whereas syntactic violations elicited a bilateral anterior negativity followed by a P600 in the implicit group and an anterior positivity followed by a P600 in the explicit group. These qualitative changes in ERP patterns corroborate the findings of longitudinal studies with classroom learners, and indicate that L2 learners at different levels of proficiency display different ERP signatures to processing the same syntactic structures.

Advanced EEG/ERP analyses to study individual differences in syntactic processing

Recently, ERP studies examining syntactic processing in L2 learners and bilinguals have developed several more advanced statistical techniques to examine individual variation in electrophysiological signals. Below we discuss studies that used correlational and regression analyses, oscillatory neural dynamics and complex network analysis, and studies that examined inter-individual variation in ERP response profiles.

Correlational and regression analyses

To gain insight into how variation in individual difference measures affects the magnitude of ERP components in the grand average waveform, correlational analyses and multiple regressions analyses can be conducted that relate the magnitude or the peak latency of an ERP component (e.g., the P600) with the score on a given test (Batterink & Neville, 2013; Tanner et al., 2013; Tanner et al., 2014; White et al., 2012). For example, Tanner et al. (2013) found that L2 learners' scores on a grammaticality judgment task of subject-verb agreement correlated positively with the magnitude of the P600 effect. A subsequent multiple regression analysis showed that performance on the subject-verb agreement judgment task, and not hours of instruction, predicted the magnitude of the P600 effect. As noted by Morgan-Short (2014), in most of these studies the behavioral assessment of proficiency was based on the same structure as presented in the ERP part of the study (but see Tanner et al., 2014), and not on a (standardized) proficiency test independent of the target syntactic

structure. Future research is needed to determine whether the relation between L2 proficiency and the amplitude of an ERP response also extends beyond the behavioral and electrophysiological measurement of a particular syntactic structure.

Finally, general additive modeling (GAM) can be applied to model non-linear relationships (or linear relationships) between predictors and the dependent variables, as has been used by Meulman et al. (2015) to examine the effect of AoA on the ERP signal in L2 learners.

Oscillatory neural dynamics and complex network analysis

ERPs reflect regularities in electrical brain activity that are time-locked to the onset of an external event. Analyses of neural oscillations via time-frequency representations (TFRs) provide an alternative method of examining neural activity via EEG during sentence processing. These TFRs index the ongoing oscillatory dynamics of the EEG signal, which reflect the (de)synchrony of functional neural networks (Bastiaansen & Hagoort, 2006). In these analyses, power, or activity, in different frequency bands (delta: 0.5 – 3 Hz; theta: 4 – 7 Hz; alpha: 8 – 12 Hz; beta: 13 – 30 Hz; gamma: above 30 Hz) in response to stimuli is of interest. An increasing number of studies are applying this technique to language processing, and this emergent literature suggests that lexico-semantic processing elicits synchronization in the theta and gamma bands (e.g., Bakker, Takashima, Van Hell, Janzen, & McQueen, 2015; Bastiaansen & Hagoort, 2006; 2015), while sentence-level syntactic processing elicits (de)synchronization in the lower beta band (e.g., Bastiaansen & Hagoort, 2015; Weiss & Mueller, 2012). Although this technique has been used in bilingual studies on syntactic processing (Kielar, Meltzer, Moreno, Alain, & Bialystok, 2014) and

translation (Grabner, Brunner, Leep, Neuper, & Pfurtscheller, 2007), to our knowledge no reported studies as of yet have used this technique to study individual differences in syntactic processing in bilinguals.

Recently, Pérez et al. (2015) employed a complex network analysis approach to study time-varying topographical properties of functional networks as extracted from EEG data. This analysis is based on a mathematical model called graph theory and models the brain as a graph whose nodes represent different regions and the links connecting nodes represent functional (or structural) connections. They examined highly proficient English-Spanish bilinguals (all late learners of L2 Spanish) whose accuracy in detecting article-noun gender agreement violations in Spanish sentences was nearly perfect, and equal to that of native Spanish speakers. Both groups were presented with Spanish sentences containing article-noun gender agreement violations and their correct counterparts. The complex network analysis found no differences between bilinguals and native speakers when they read correct sentences without any violation. However, for the late L2 learners, a lower degree of parallel information transfer and a slower propagation between regions was found for incorrect relative to correct sentences. No such differences were found for the native speakers. This analysis suggests that even in highly proficient L2 learners (whose accuracy scores were similar to native speakers) the neural network activation pattern is configured differently than in native speakers. This type of analysis is a promising avenue to gain more insight into individual variation in L2 learning trajectories among L2 speakers, and the factors that potentially modulate brain network activation patterns associated with L2 syntactic processing.

Inter-individual variation in electrophysiological response profiles

Studies using ERPs typically report grand average ERP waveforms across participants, and not each participant's individual waveform. Individual waveforms vary substantially across individuals in terms of the amplitudes and latencies of ERP components, and this inter-individual variability is lost when calculating the grand average ERP waveform.

Several recent studies have shown that biphasic negative-positive grand mean ERP waveforms (e.g., an N400 followed by a P600) can be a result of averaging across individuals who show different ERP response profiles (e.g., Tanner et al., 2013; Tanner et al., 2014; Tanner & Van Hell, 2014). For example, testing proficient Spanish-English bilinguals, Tanner et al. (2014) observed an N400-P600 grand average waveform in response to subject-verb agreement violations in L2 English, but subsequent computations of the response-dominance index (RDI) showed that violations of subject-verb number agreement elicited N400 effects in some individuals and P600 effects in others. Similar patterns have been found in monolingual native English speakers processing violations of core morphosyntactic constraints in English (Tanner & Van Hell, 2014).

In short, the RDI is computed as follows (see formula below; for more detailed information, see Tanner et al., 2014 and Tanner & Van Hell, 2014). For each individual, mean activity is computed over a centro-parietal region of interest (ROI) where N400 and P600 effects are typically largest. Within this ROI, each individual's N400 effect magnitude and P600 effect magnitude are calculated. Each individual's response dominance can then be quantified and plotted by fitting the individual's least squares distance from the equal effect sizes lines using perpendicular offsets. RDI values near zero reflect relatively equal-sized N400 and P600 effects, whereas more

negative or positive values reflect relative dominance of a negativity or positivity across both time windows, respectively.

$$RDI = \frac{(P600_{ungrammatical} - P600_{grammatical}) - (N400_{grammatical} - N400_{ungrammatical})}{\sqrt{2}}$$

Abdollahi and Van Hell (2016) conducted RDI analyses to study individual response profiles in intermediate classroom learners of L2 Spanish. Materials consisted of L2 Spanish sentences that had similar or dissimilar syntactic structures across L2 Spanish and L1 English, or were unique to the L2 (cf., Tokowicz & MacWhinney, 2005), as well as L1 English sentences with three different syntactic structures. Participants were visually presented with grammatically correct and incorrect variants of these sentences. Here we will discuss the data for adults reading unique L2 Spanish sentences (with and without determiner gender agreement violations, e.g., **Tengo el pluma en mi mochila*. 'I have the pen in my backpack.') and L1 English sentences (with and without subject verb agreement violations, e.g., **We do not has a lot of money*.). Though these adult learners were in their third semester of Spanish at the university level, ERP responses to L2 determiner gender agreement violations yielded no significant effects. The learners did show a typical P600 effect for subject-verb agreement violation in their L1 English.

The absence of a significant effect in L2 processing was unexpected: these were intermediate L2 learners and Tokowicz and MacWhinney (2005), who tested L2 learners at a similar proficiency level, did observe a P600 to L2 determiner gender agreement violations. Subsequent RDI analyses revealed that different individual response profiles conflated the grand average waveform. About half the L2 learners showed a P600-response dominance, whereas the other half showed an N400-response dominance in L2 processing. The RDI outcomes for L1 processing showed

that the large majority of individuals demonstrated a strong P600-response dominance (in line with the significant P600 effect found in the group-analysis).

These RDI analyses provide insight into individual ERP response patterns, and variability therein, and may help to understand why typical syntactic ERP signatures may or may not materialize in grand average waveforms.

Conclusions

Relative to the wealth of studies on individual differences in L2 syntactic processing that take a behavioral approach, the number of ERP studies examining individual variation in L2 processing is small. Moreover, the large majority of these ERP studies focused on the role of AoA and/or L2 proficiency. Nevertheless, these studies have provided valuable insights into how AoA and L2 proficiency modulate L2 syntactic processing, and demonstrate that variability in AoA and L2 proficiency yields qualitative and quantitative differences in L2 syntactic processing. In moving forward, future research should embrace a wider range of individual differences measures, and study how variability in working memory and executive functions, aptitude, motivation, learning styles, and personality impact electrophysiological correlates of L2 syntactic processing. Another promising avenue for future research is the use of more advanced statistical techniques to model inter-individual variation in ERP response profiles and to study oscillatory neural dynamics and neural network activation patterns associated with L2 syntactic processing.

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