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Neurocognition of Social Learning of L2: How can L2 be learned as L1?

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Abstract

This chapter focuses on the social second language learning (SL2) framework, which considers second language (L2) learning through social interaction and integration of information in the real world or in simulated social contexts. Specifically, the chapter discusses how SL2 provides a new framework for thinking about L2 versus first language (L1) differences and their corresponding neural correlates. The chapter compares the manner and context in which adults typically learn L2 with the way children naturally acquire L1, pointing to the significant theoretical implications of SL2. Then, properties are identified that make SL2 distinctive and advantageous to L2 learners, with a discussion of how this framework can be applied to the study of theoretical issues underlying L2 learning. Additionally, the chapter discusses the neural representations with respect to the increasing recognition of the right-hemisphere participation in SL2. Finally, the practical applications in technology-enhanced language learning are highlighted.

Introduction

Both folk wisdom and scientific knowledge have pointed to the apparent differences between children and adults in language learning, especially with regard to how native language (L1) acquisition versus second language (L2) learning differ. As compared with child L1 learning, adult L2 learning not only tends to be less successful, but also displays highly variable learning outcomes across individuals. According to the critical period hypothesis (Lenneberg, 1967), such differences are due to biological constraints including the timing of maturation of brain functions (e.g., hemispheric lateralization). In contrast to the original critical period hypothesis, Johnson and Newport (1989) suggested the possibility of a cognitive account of how mechanisms of learning differ in children versus adults, with particular reference to the way linguistic input is processed and analyzed. More recent theories further suggest that the learning principles may not be fundamentally different between L1 and L2, but the context, conditions, and environmental support to children and adults are very different (i.e., different ecosystems; see Claussenius-Kalman et al., 2021), along with different methods and manners of learning. For example, most adult learners do not have the same opportunities for language learning as children (Caldwell-Harris & MacWhinney, 2023; MacWhinney, 2012).

In this chapter, we attempt to provide a framework to address the issue of whether and how L2 learning by adults can occur like L1 learning by children. The framework called social L2 learning (SL2) assumes that L2 learning, especially beyond the sensitive period, may benefit from social interaction and enriched exposure in real-life, as in L1 learning. SL2 also highlights the neurocognitive correlates of perception, action, and multimodal processing of information relevant to the target L2 environment in real-world or simulated contexts (see Li & Jeong, 2020 for the details). In this chapter, we first provide the key dimensions of the context and conditions under which children and adults learn. Then, we will highlight in particular the social and affective dimensions of language learning, along with the underlying cognitive and neural correlates that reflect learning differences.

Benefits of Social-Based Language Learning: Some Theoretical Considerations

The remarkable ability for an infant to acquire any human language has led to some scholars, most notably Chomsky (1981), to argue for an innate "language acquisition device" or "universal grammar". Because this theoretical approach focuses only on innate mechanisms as the core principles that prepare humans to learn a language (the capacity or competence), they ignore the learning process itself. In other words, the learning process could be impacted by a host of environmental and social factors, but these factors are performance-related, and are external to the linguistic competence of the individual. However, as cognitive science breaks the boundaries of language and cognition and abandons the 'modularity' hypothesis of Fodor (1983), which posits that language is an independent and separate module from the rest of cognition (perception, memory, vision), it is important for us to look at how children actually acquire language from the social environment and through social interactions (e.g., Kuhl, 2004).

When we start to look at social-based language learning process, we quickly see that adults learn languages with very different methods and conditions that differ from children learning their L1 (for information on child L2 neurocognition, see Ortiz Villalobos et al., this volume). An L1 is naturally learned and acquired in a safe interpersonal space where the child integrates multidimensional linguistic forms (e.g., spelling, grammar, pronunciation) with their meanings, integrates multimodal information from auditory, visual, and tactile channels, and incorporates the actions and intentions of parents and peers (Bloom, 2000; Tomasello, 2003). Such learning allows children to integrate the rich sensory and perceptual experiences of the environment, interacting with objects and people, and performing actions. By contrast, perhaps most often, L2 acquisition in adults takes place in an instructional context, that is, the classroom. For example, in Asian countries, learners of English as a foreign language are often asked to perform mechanical memory-based grammar drills, word translations, comprehension checks, and reading aloud, with limited input and practical language use in the social context and limited interpersonal social interactions. These traditional learning experiences may weakly connect word forms, meanings, and concepts, resulting in poor semantic representations that may be parasitic on L1 representations (see Bowden & Faretta-Stutenberg, this volume, for more L2 neurocognition and L2 learning contexts).

Below we draw from conceptual frameworks in psycholinguistics, memory, and cognitive theories to discuss first how L1 is learned and then what the benefits are when L2 is learned like L1.

Social Interaction

In the *New Science of Learning* framework, language learning is a social-based process, supported by computational mechanisms and a neural circuit that supports and links cognition, perception, and action (Meltzoff et al., 2009). Children rely on a multitude of social cues such as eye gazes, facial expressions, and the intention of others, in order to understand what they need to learn and when. Computation models based on data from mother-child interactions, which consider social cues tend to perform better than models without those cues (Li & Zhao, 2017; Yu & Ballard, 2007). In social interaction, joint attention (i.e., two social partners looking at the same object) is essential for early language learning and social skill development (Sanchez-Alonso & Aslin, 2022, for a review). During joint attention, a child is susceptible to eye gazes from his/her parents/caregivers and adjusts his/her attention. For example, Yu and Smith (2016) found that parents' gaze toward toys positively facilitated infants' attention to the toys and guided them to avoid distractions. For joint attention to play a significant role, contingent, reciprocal interaction between infants and parents is the key: Reciprocal interaction improves a range of skills such as sustained attention and social skills (i.e., self-regulating and engaging conscious control of one's attention).

Social interaction is imperative when infants and toddlers learn languages (Hakuno et al., 2017; Kuhl et al., 2003). A baby's ability to recognize the differences between the sounds of all languages declines between 6 and 12 months of age (Kuhl, 2004). Kuhl et al. investigated sufficient conditions when such a decline in foreign-language phonetic perception may be delayed. Only infants exposed to a live tutor, not the recorded video or audiotape conditions, showed similar discrimination ability to native speakers. Although the presence of a live person is a clear advantage (compared to recorded videos), children can also learn languages from video chat with a partner, as long as they can interact with their partner, suggesting the importance of social contingency for learning (Myers et al., 2017).

While interacting with others, children are sensitive to the speaker's goal and communicative intentions, and use these cues to infer word meanings (Frank & Goodman, 2014). This ability is related to theory of mind and social reasoning skills. Although research with adults is still limited, recent studies have shown that for adults as well, face-to-face interactions, social response contingency, and social signals from others can lead to more effective learning by promoting higher levels of attention, motivation, and emotional arousal (Caldwell-Harris et al., 2014; Verga & Kotz, 2017, 2019). This line of research indicates the importance of social interaction in language learning and other types of learning, regardless of age.

Embodied Cognition

Action-based experiences, such as those that occur during L1 acquisition, are likely to help the child build sensory and motor-based semantic representations in the brain. Based on embodied cognition theory (Barsalou, 2008), our mental representation of concepts, objects, and behaviors is embedded in our experiences of the body (e.g., mouth, hands, feet), as well as our experiences in specific modalities (e.g., auditory, visual, tactile). Therefore, semantic/conceptual knowledge appears to be represented in the distributed networks associated with experiential information such as perception, sensation, movement, hearing, and emotion in real-life (see Meteyard et al., 2012 for a review). Behavioral and neurocognitive studies have so far mainly examined native L1 speakers in providing supportive evidence for the embodied cognition hypothesis (e.g., Aziz-Zadeh & Damasio, 2008; Gianelli & Dalla Volta, 2015). The limited number of neurocognitive L2 and bilingual studies have reported that, unlike in L1, the sensory-motor areas were not strongly engaged in processing action-related words and sentences in the L2 (Xue et al., 2015; Zhang et al., 2020). This finding suggests that the L2 representation in bilinguals (especially late learners) is less embodied than their L1 representations. Different learning conditions, such as the age at which learners begin to learn L2 (i.e., age of acquisition), limited real-life experiences (i.e., L2 exposure), and L2 proficiency levels, may all influence the degree of L2 embodiment (Hernandez & Li, 2007; Zappa & Frenck-Mestre, this volume).

There is still little evidence that body-specific and modality-specific experiences during learning would affect L2 representation, although a few recent studies have provided some initial evidence for embodiment effects in the brain (Legault, Fang, et al., 2019; Mayer et al., 2015). For example, Mayer et al. (2015) compared L2 vocabulary learning under three conditions: performing gestures, viewing pictures, and no-enrichment control. When performing a translation task inside fMRI (functional magnetic resonance imaging; see Kousaie & Klein, this volume for more on this neuroimaging method) after learning, participants who learned words with pictures showed activity in the right lateral occipital cortex, whereas those who learned words with gestures had more activity in the posterior superior temporal sulcus and in the premotor area, regions that have been implicated in multimodal and action-based information processing. Critically, brain activation in superior temporal sulcus and premotor cortex was significantly correlated with behavioral performance. The L2 learners showed significantly greater retention for words learned with gestures than those with pictures, even after two to six months. These results indicate that body-specific activities are essential for adult L2 learning and are consistent with sensorimotor-based neural explanations of semantic representation.

Multimodal Learning and Elaborative Processing

The disparity between L1 and L2 during learning with respect to both qualitative and quantitative information processing may lead to different degrees of the richness of semantic representation in the acquisition of two languages, which profoundly impacts successful memory retrieval, as suggested by previous memory research (Craik & Lockhart, 1972; Tulving & Thomson, 1973). According to the 'encoding specificity principle' (Tulving & Thomson,1973), semantic memories have the best chance of being retrieved if recalled in the context in which they were initially encoded than otherwise. A similar memory hypothesis, 'level of processing theory' (Craik & Lockhart, 1972), also suggests that more elaborate semantic processing during learning leads to more successful retrieval than shallow or superficial processing of the same items.

Social learning involves elaborative semantic processing using various social cues and multimodal information for language acquisition. The 'dual coding theory' (Paivio, 1990) and the 'multimedia learning theory' (Mayer, 2014) both support the notion that the elaborate processing of multimodal information enhances the quality of semantic memory. Specifically, Mayer and colleagues have postulated several principles that account for why people learn better and build better mental representations with multimodal information (text, video, animation) than with information of only one modality. For example, processing text with pictures and images is more effective than that of text alone, indicating the multimodal advantage in both behavior and in the brain (e.g., Liu et al., 2020). Furthermore, recent cognitive neuroscience research suggests that deep/elaborative encoding (involving active discovery, multiple sources of information, and social/emotional processing) boosts cortical activity during encoding, and this cortical activation plays a vital role in retaining information in long-term memory (see Hebscher et al., 2019, for a review). This perspective is consistent with emerging brain evidence that elaborative SL2 leads to the successful long-term effect of learning (Jeong et al., 2021; Legault, Fang, et al., 2019; Mayer et al., 2015). This evidence will be reviewed in more detail below.

Emergentist Perspectives of Language Learning

The competition model provides social-based and emergentist explanations of the distinctions between L1 and L2 learning (Hernandez & Li, 2007; MacWhinney, 2012; see a recent volume in emergentist approaches to language; MacWhinney et al., 2022). According to MacWhinney (2012), adult language learning is susceptible to several major "risk factors" that may be particularly strong in late adults. Such risk factors include (a) thinking in L1 only, which implies the need to translate from L2 to L1 rather than directly using L2, (b) social isolation, which means learning occurs in an individual or within-group communities, and (c) the lack of perception-action embodied contexts due to lack of real-life experiences in language learning. In particular, the lack of perception-action embodied contexts may explain why adult learners' parasitic L2-on-L1 representations are strengthened to a high level (Zhao & Li, 2010). However, if adults are offered rich environmental support in the learning context, similar to children, their L2 learning may be better positioned to fend off these risk factors. This can result in the development of inner speech in L2, social integration, and independent representations of L2, separate from L1 (Li, 2013; Li & Jeong, 2020).

Added to the risk factors facing adults is a consolidated L1, often precluding the L2 of adults, especially late adult learners, from reaching a level of native competency. Adults usually begin learning L2 after establishing their L1, which facilitates the association of L2 to L1 translation, but greater experience in learning and use of L2 in real-life situations may enhance the direct connection between L2 words and objects/concepts (see Kroll & Stewart, 1994). Research findings that study-abroad experiences of late learners tend to weaken the interference of L1 on L2 may support the importance of social experiences in language learning (Linck et al., 2009).

Such series of empirical and theoretical studies imply that language learning does not occur solely as an individual cognitive activity; by contrast, language experience in real life is deeply involved in learning and processing L2 through interaction with others. This notion is consistent with historical and recent trends in various fields of language studies: sociocultural theory (Lantolf, 2006), usage-based learning (Ellis, 2019), interaction hypotheses (Mackey et al., 2012) and neuroemergentism (Claussenius-Kalman et al., 2021). All of these perspectives emphasize the characteristics and conditions of social interaction and learning environments.

Neural Representations of Social L2 Learning

Different Brain Networks for L1 vs. L2

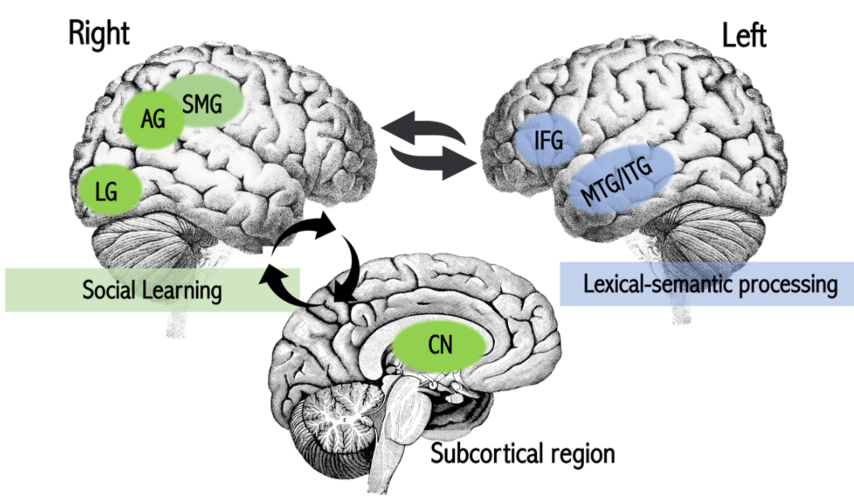
Although it is clear that L2 researchers are now paying more attention to the role of social learning, relatively few studies in the past have tapped into the neural substrates of SL2. Many neuroimaging studies have been performed in the domain of L2 learning, but so far, most of them have focused on brain changes as a result of L2 learning experiences (see Abutalebi et al., 2005; Li et al., 2014, for reviews). In addition, most published neuroimging studies have relied on traditional learning tasks, such as rote memorization and translation training, either in the classroom or lab-based intensive training settings (e.g., Breitenstein et al., 2005; Grant et al., 2015; Qi et al., 2015; Yang et al., 2015). Generally, findings from these studies suggest that classic language-related brain networks (e.g., frontoparietal area) and memory-related brain regions (e.g., hippocampus) in the left hemisphere are involved in learning and consolidating linguistic information. Such findings, however, may be insufficient to reveal the potential differences between L1 and L2 brain networks when the two languages are learned differently. Despite the argument that the same neural substrates may be recruited for L2 as for L1 processing (Abutalebi et al., 2005; Abutalebi & Green, 2007), there is now growing evidence that L1 vs. L2 processing and representation may involve the same regions but different brain network configurations or computations (Li, 2013; Xu et al., 2017). Specifically, new brain data suggest that the connectivity patterns in semantic representation may significantly differ between L1 and L2. For example, Zhang et al. (2020) showed that the processing of nouns and verbs in L1 engages a more integrated network that connects language areas with sensorimotor processing and semantic integration regions (e.g., caudate nucleus and supramarginal gyrus), whereas such connections are weak or absent in L2 processing even for highly proficient L2 speakers.

In contrast to the results of previous studies of traditional learning, recent studies on social-based L2 learning are beginning to provide new evidence that such L1-L2 differences may be attenuated, as SL2 positively influences successful learning of the L2 and enhances the semantic representation of the L2 with embodied, multimodal, and richer contextual information. Furthermore, the cognitive demands during social learning similar to L1 may influence the development of the brain systems underlying L2 knowledge (see Li & Jeong 2020, for a review), making L1 and L2 representations more on a par with each other. In what follows, we provide an overview of some neural evidence on how adult foreign language learning can be optimally facilitated by incorporating some features of social learning.

Role of the Right Hemisphere: Temporal-Parietal Junction and Adjacent Regions

Previous studies on SL2 have consistently reported that the activation of the right-hemisphere brain regions, including social cognition and action perception areas as well as both cortical and subcortical areas, play an essential role in SL2 (e.g., , Jeong et al., 2021; Jeong et al., 2010; Legault, Fang, et al., 2019; Verga & Kotz, 2019; see Li & Jeong 2020, for a review) (see Figure 16.1).

Figure 16.1
The neural network underlying social L2 learning



Note. The left hemisphere regions (blue) control lexical-semantic processing, whereas the right hemisphere cortical plus the subcortical regions (green) engage in social learning. IFG = inferior frontal gyrus; SMG = supramarginal gyrus; AG = angular gyrus; LG = lingual gyrus; CN = caudate nucleus; MTG/ITG = middle temporal gyrus/inferior temporal gyrus. (From Li & Jeong, 2020; reproduced with permission from Springer Nature.)

Most of these previous studies on SL2 showed involvement the right temporal-parietal junction (TPJ) and adjacent areas such as the right inferior parietal lobule, including supramarginal gyrus (SMG) and angular gyrus. The right TPJ has been implicated as a multimodal association area that integrates multisensory information (Carter & Huettel, 2013). This region has long been recognized as one of the social cognition areas associated with the perception of various social stimuli, attention to social cues, and higher cognitive processing of social reasoning such as theory of mind (i.e., thinking about the beliefs, emotions, and intentions of others) (e.g., Deen et al., 2015). For example, Jeong et al. (2010), one of the initial studies on SL2, trained Japanese native speakers to learn Korean words under the following two conditions: (a) L1 translation and (b) simulated video. The stimulated videos included joint activities using target words in real-life situations (e.g., a video showing an actor trying to move a heavy bag and asking another actor for help, using the L2 target Korean word *dowajo* which means *help me* in English). After participants had remembered all the target words, they performed a retrieval task (i.e., testing) inside the MRI scanner. Results showed that the right SMG became more activated when retrieving words learned through simulated videos than words learned through translation. Also, brain activity in the right SMG for processing L2 words encoded via stimulated videos was similar to processing the participants' L1 words (learned through daily life as a child). Jeong et al. interpreted these results as suggesting that L2 words learned through real-life situations might be processed similarly to L1 words in the brain, even when the learning was conducted through simulated videos in relatively short sessions.

In a follow-up study, Jeong et al. (2021) used the same learning conditions (simulated video vs. L1 translation) to determine the extent to which the qualitative and quantitative involvement of brain systems during actual form-meaning mapping (i.e., encoding) affects the acquisition of semantic representations of L2 words. The left inferior frontal gyrus (one of the core language-related areas) was activated during learning in both social learning and L1 translation conditions. In contrast, the social learning condition uniquely induced neural activation in the right inferior parietal lobule, the posterior superior temporal sulcus, and the posterior middle temporal gyrus. These areas may have been engaged due to processing of multiple perceptual, action-related, social, and emotional cues in the simulated real-life video condition. Consistent with the encoding theories mentioned earlier, such elaborative cognitive processes during learning may have led to the more enriched semantic representation of L2 words.

Notably, successful learners in the social learning condition recruited the right TPJ, motor areas (post and precentral areas), and right hippocampus more strongly than did less successful learners. In Jeong et al. (2021), those who had higher activation in the right TPJ, motor areas, and right hippocampus during the initial stage of learning performed significantly better on a delayed vocabulary test where they applied target words to novel social situations. In contrast, those who encoded L2 words through L1 translation did not perform as well in novel contexts when recalling the L2 words. They may have relied on rote associative memory processes for L1-L2 word pairs in the translation condition, resulting in surface and weaker encoding of words. It is interesting to note that the L1-translation learners recruited only limited brain areas (e.g., left inferior frontal gyrus) as compared with the SL2 learners during encoding. Thus, SL2 may be a successful learning process that can lead to an integrated brain network to support multimodal integration, social reasoning, motor simulation, and long-term memory.

The crucial role of the right inferior parietal lobule, including both SMG and angular gyrus, in social learning has also been supported by experiments with virtual reality (VR)-based interactive learning of L2 words. Legault, Fang et al. (2019) investigated the differential effects of different learning contexts on structural brain changes. Two groups of English L1 speakers participated in Chinese vocabulary learning with a paired picture-word association or VR environment training for 20 days. The VR group engaged in an interactive 3D environment in which they dynamically interacted with target words such as objects and animals. It was found that intensive VR vocabulary learning enhanced the cortical thickness of the right SMG compared to L2-picture associative learning (within the same amount of time and learning the same material). Furthermore, its cortical thickness showed a positive correlation with better scores at a delayed retention test.

Verga and Kotz (2019) reported that the right SMG was more activated in simulated partner-based word learning than individual-based learning when their participants explored the meanings of target words with contextual information. Also, during partner-based learning, activity in the right lingual gyrus and right caudate nucleus, known as the visuospatial attentional network, correlated with better temporal coordination between a learner and a partner. Furthermore, learners with greater right inferior frontal gyrus activity showed better learning outcomes during the partner-based learning condition, but there was no such correlation in the individual-based learning condition. Unlike L2 classroom learning contexts in which social cues are generally not present, these findings suggest that awareness of partners during social interaction facilitates L2 learning success by directing learners' attention to the correct L2 referent from alternative mappings, in a similar way as social cues can enhance L1 acquisition (e.g., Kuhl, 2004; Yu & Smith, 2016). This effect is further identified in an fMRI study (Jeong et al., 2011) that showed that L2 learners are more responsive to a live person than a recorded person when communicating in L2 (cf. Kuhl et al., 2003). The live person condition activated more brain regions associated with L1 communication than the recorded person condition.

There is also supportive evidence that adaptive and social enriched exposure can change the substantial neural plasticity of L2 phonetic perception in adulthood (Zhang et al., 2009). Zhang et al. stimulated multimodal and enriched exposure of English sound categories (/r/ and /l/) to Japanese adults who had received limited English exposure. They used a computer-adaptive training program with visible facial articulation cues, acoustic exaggeration, and high multiple-talker variability. They measured brain changes by magnetoencephalography with an oddball task before and after intensive training for two weeks. Enriched exposure induced significant improvement of speech discrimination scores, and enhanced neural senstivity to phonetic destinction and neural efficiency during passive listening. Furtheremore, behavioral improvement was positively correlated with increased neurophysiological response. This finding suggests that enriched exposure develops new memory traces of L2 phonetic representations in the adult brain.

In summary, the previous findings suggest that SL2 may result in stronger activation of brain regions or networks linked to multimodal, visual, and spatial processing, social, affective, and perception-action-related processing, enhancing the rich semantic representation of L2 (Jeong, et al., 2021; Jeong, et al., 2010; Legault, Fang, et al., 2019; Verga & Kotz, 2019). Contrary to the notion that a child's brain, not an adult's, is sensitive to social cues in learning, such studies show that the adult brain also exhibits significant neuroplasticity and changes in response to social learning even during short-term training. When L2 words are initially learned in a socially interactive condition (even in a simulated context, Jeong et al., 2010), those words could be stored and processed in the same brain area as L1 words.

Practical Applications in Rechnology-Enhanced Social L2 Learning

The theoretical and empirical evidence reviewed so far suggests that social learning not only positively impacts L2 learning success but also leads to the neural representation of L2 more similar to that of L1 due to its enriched, embodied, and multimodal information. However, it is often difficult to provide adults directly with a rich social learning environment similar to what children receive for L1 acquisition. One way is for adults to study abroad. Although it is undoubtedly effective for L2 learning, studying abroad is not practical or feasible for everyone due to its costs, time, and family separation. Li and Lan (2021a) suggest that digital language learning (DLL) can be one of the best solutions for providing an environment conducive to social learning (e.g, VR, mobile-assisted language learning, game-based language learning, and even robot-assisted language learning). For example, Legault, Fang et al. (2019) is a VR study that found that simulated physical interaction with objects allowed participants to acquire L2 words like in L1 contexts, leading to a positive impact on the learner's brain functionally and anatomically.

Another potential use of DLLs is to facilitate the affective and emotional processing of L2, which is often lacking in the traditional language classroom. Recently developed DLL tools and platforms may provide L2 learners with reciprocal feedback and social reward during learning. For example, automatic feedback may be embedded in mobile-assisted language learning apps, avatars with emotional expressions can be built in VR platforms, and performance-contingent rewards can be a feature of game-based language learning (Park et al., 2019). Social interaction is one of the most crucial contributors to L2 learning motivation in applied linguistics (MacIntyre et al., 2011). This is supported by a brain imaging study (Ripollés et al., 2014) that shows that feedback during learning increased activation of the reward system in the brain, which in turn fostered motivation to learn.

Adult L2 learning is affected by individual cognitive abilities and learner characteristics (e.g., L1 background, age, proficiency, motivation, aptitude, working memory; for more on L2 neurocognition and individual differences, see Luque & Covey, this volume). DLL learning may be able to provide methods for both revealing and reducing these individual differences due to the design features and its connection to big data analytics. For example, Legault, Zhao et al. (2019) found that the outcome of learning for successful learners was high in both VR and non-VR conditions, but for less successful learners, the VR condition significantly facilitated their learning. In other words, VR learning assisted and facilitated L2 learning for learners who are typically “struggling” in the language classroom. Thus, it appears that VR may benefit some individual learners more than others.

This last example points to a future research direction for understanding the interaction between technology and the learner (see Li & Lan, 2021b), which will enable us to develop learning platforms to accommodate the characteristics and needs of individual learners with the specific design features of VR and DLL more generally. With DLL tools, students do not have to limit their language learning experience in the classroom, and can learn L2 anywhere and anytime. For researchers, this provides a unique opportunity to study and track individual learners in terms of their cognitive and linguistic abilities and profiles over time, and develop curriculum that is tailor-made to individual students’ learning to promote learning success. This will ride on the tide of the so-called ‘personalized learning,’ for not only language learning but education in general. Consequently, big data analytics based on machine learning and artificial intelligence will also have a prominent place in L2 learning and education (see a recent call for integration in Luan et al., 2020).

Future Directions

In this chapter, we have provided an overview of the framework of SL2 and the theoretical models and hypotheses that support social learning for language acquisition in general, and we reviewed the neural evidence that supports the SL2 framework, showing significantly different brain networks may be implicated in social-based learning as compared with those in traditional classroom-based learning. Further, we suggested that it is possible to leverage the rapidly developing digital technologies to simulate the conditions of social learning, which may produce the relevant neural and cognitive changes in the brain.

There are a number of new exciting avenues along which we can pursue future studies in this domain. The first avenue is to examine the neural basis of social interaction at the interpersonal level. As discussed in Li and Jeong (2020; see their Figure 1), whereas previous research has focused primarily on the structure and function of individual brains (i.e., single brain), the hyperscanning approach (i.e., inter-brain) allows the investigation of real-time dynamics between two or more interacting brains during social interaction (e.g., Redcay & Schilbach, 2019). Recent advances in both imaging technologies and the data analytics have enabled us to pursue this exciting research direction (e.g., Noah et al., 2020; Piazza et al., 2020). The second possibility is to study the role of motivation and emotion as important ingredients of learning to accelerate SL2. It is essential to understand how SL2 influences affective processing (e.g., emotion and motivation) and how it interacts with the limbic and subcortical reward systems of the brain during SL2. The third approach is to use machine learning to analyze large-scale real-time interaction data to identify individual learner profiles, with the aim of providing personalized learning (e.g., through feedback and reciprocal interpersonal interactions) as in real social learning (see also Li & Lan, 2021a). Adult L2 learning can be expected to develop to greater levels of success than in traditional learning contexts if we can capitalize on technology-enhanced language learning and optimized social learning that incorporates key dimensions of individual differences. Finally, to understand different aspects of L2 learning from multi-level language systems, future studies should extend their focus from the lexico-semantic level to phonological, morphological, syntactic, and discourse levels with the SL2 approach (Hagoort, 2019).

Further Readings

This article provides a first attempt at integrating the theoretical, empirical, and neural bases of SL2 framework.

Li, P., & Jeong, H. (2020). The social brain of language: Grounding second language learning in social interaction. *npj Science of Learning, 5*, Article 8. https://doi.org/10.1038/s41539-020-0068-7

This article provides an overview of the current trends and future promises of DLL for L2 from a neurocognitive approach. (see also the accompanying article that discusses the interaction between technology and the learner: Li & Lan 2021b in the *References* below)

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