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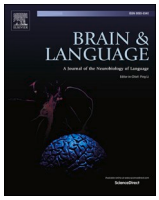

Age effects in second language acquisition: Expanding the emergentist account

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ABSTRACT

In 2005, Science magazine designated the problem of accounting for difficulties in L2 (second language) learning as one of the 125 outstanding challenges facing scientific research. A maturationally-based sensitive period has long been the favorite explanation for why ultimate foreign language attainment declines with age-of-acquisition. However, no genetic or neurobiological mechanisms for limiting language learning have yet been identified. At the same time, we know that cognitive, social, and motivational factors change in complex ways across the human lifespan. Emergentist theory provides a framework for relating these changes to variation in the success of L2 learning. The great variability in patterns of learning, attainment, and loss across ages, social groups, and linguistic levels provides the core motivation for the emergentist approach. Our synthesis incorporates three groups of factors which change systematically with age: environmental supports, cognitive abilities, and motivation for language learning. This extended emergentist account explains why and when second language succeeds for some children and adults and fails for others.

1. Introduction

Researchers have often suggested that language learning is constrained by the expiration of a critical or sensitive period (DeKeyser, 2000; Lenneberg, 1967). This claim has been referred to as the Critical Period Hypothesis (CPH). The original motivation for the CPH was adults' observed difficulty in learning a new language, compared to children's apparently more rapid learning of a new language (Lenneberg, 1967). Systematic data was obtained by testing the grammatical abilities of adults who had immigrated years or even decades earlier. Those who immigrated in childhood demonstrated greater second language (L2) knowledge than those who immigrated in adulthood (Johnson & Newport, 1989; DeKeyser & Larson-Hall, 2005; Abrahamsson & Hyltenstam, (2009). This data was long viewed as strong support for puberty as marking the end of a critical period for language learning. However, statistical analysis of these studies indicated that those learning outcomes were fit better by a linear decline in ultimate attainment as a function of age of acquisition rather than a sharp decline at some critical transition period, such as puberty (Bialystok & Hakuta, 1999; Birdsong, 2005; Hakuta et al., 2003; Vanhove, 2013).

Alternatives to the CPH emphasize the role of environmental, social, cognitive, motivational, and developmental factors in shaping how age influences L2 acquisition (Dörnyei, 2009; Marinova-Todd et al., 2000; Singleton & Pfenninger, 2019). These alternatives do not seek to exclude possible contributions of biological processes to age effects and the details of L2 learning. Instead, they regard variations in endogenous biological effects as ways of understanding variation in L2 learning, along with the additional cognitive, social, and motivational forces. Our purpose here is to expand on and systematize consideration of these multiple effects by linking them into the broader theory of language emergence.

Emergentist (MacWhinney, 2015) explanations propose that linguistic complexity and diversity emerge from competitions and coalitions (MacWhinney, 2021a) involving communicative functions and cognitive constraints. The theory has three components or dimensions: competition, hierarchical levels, and time/process frames or scales. Operations across these three dimensions are controlled by constraints that come into play once a structure emerges to a new level in a new timeframe. These three dimensions are useful for understanding processes as diverse as state transitions for water (Greenwood & Earnshaw, 2012), foraging in honeybees (Menzel & Giurfa, 2001) and the storage of memories in frontal cortex (Koechlin & Summerfield, 2007).

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Darwin (1859) articulated the theory of competition (the first component of emergentist explanations) in terms of the processes of proliferation, competition, selection, and adaptation. Within cognitive psychology, selectionist principles have been used to account for areas as diverse as neurogenesis (Edelman, 1987), developmental neurological specialization (Hernandez et al., 2019), language processing (MacWhinney & Bates, 1989), language change (MacWhinney et al., 2014), social pattern learning (Mesoudi et al., 2006), motor control (Chang & Guenther, 2020), mathematical development (Siegler, 2006), and memory (Rosenbaum, 2015). Cognitive models often rely on selectionist processes such as winner-take-all, interactive activation, or synaptic pruning. The online effects of competition reveal themselves in speech errors (Dell, 1995), lexical competition (Nozari et al., 2011), stuttering (Chang & Guenther, 2020), and code-switching (Poplack & Cacoullos, 2015).

The second component of the emergentist account focuses on the emergence of hierarchical levels. Standard structural linguistic analysis (O'Grady et al., 1997) recognizes the six levels of discourse, syntax, morphology, lexicon, articulation, and audition. We further assume that these levels have some mapping, albeit complex, to structural brain areas and functional neural circuits (Hagoort, 2013; Kemmerer, 2015). Usage-based linguistics (Diessel, 2017) emphasizes the role of proliferation of forms and functions on each linguistic level, as well as the constraints governing the mapping of forms to functions (Bates et al., 1979).

The third component of emergentist explanation, the role of time/process, reveals its importance most clearly in fields such as Geology, Cosmology, and Evolutionary Biology. With the exception of Sociolinguistics (Labov, 2001), timeframes have received relatively less attention from Linguistics and Psycholinguistics. However, recent analyses (Anderson, 2002; Honey et al., 2017; Koechlin & Summerfield, 2007; MacWhinney, 2015; Raczaszek-Leonardi, 2010) are paying increased attention to timescale. Timeframe analyses examine the shaping of structures across timescales ranging from the milliseconds of neural firing and muscle movements up to the decades and centuries of lifespan development and language change. Each timescale is grounded on its own set of processes operating across levels. This component of emergentist theory is particularly important for understanding L2 learning, because this learning involves processes operating across such a wide variety of timescales from the moment of interaction to the lifespan of the learner.

The operation of a simple emergentist account can be illustrated by considering the processes, structures, and constraints arising on the four levels of protein folding (Campbell et al., 1999). The primary level structure of the protein is determined by the sequence of amino acids in the chain of RNA used by the ribosome as the template for protein synthesis. This chain then folds into a secondary structure of coils and folds created by hydrogen bonding across the amino acid chain. These bonding forces can only impact the geometry of the protein once the primary structure is released from the ribosome and begins to contract. Next, a tertiary structure emerges from hydrophobic reactions and disulfide bridges across the folds and coils of the secondary structures. Finally, the quaternary structure derives from the aggregation of polypeptide subunits based on the ternary structures. The emergence of structure on each of these four levels is constrained by processes unique to each level. Protein folding takes only a couple of seconds. However, once a protein emerges from this process, it enters further competitions and constraints in biochemical pathways across longer timescales. Modeling these processes on the four structural levels and beyond is the central challenge for the field of proteomics (Aslam et al., 2017). Emergentism provides a way of conceptualizing this great diversity of outcomes in protein shape and function.

For language learning, emergentism also provides a way of understanding the diversity of outcomes. Language learning is much more complex than protein folding. However, like protein folding, language learning involves constraints and competitions operating across divergent time/process frames. For example, we can study how third graders acquire the concept of *symmetry* (Lesh & Lehrer, 2000) in the context of a year-long module on geometric concepts. At the beginning of the year, students are introduced to the concept through a story about two sisters working to create a symmetric patchwork quilt. Then, they are asked to illustrate the concept with some other material. Some of their earliest meanings relate to equality and similar color patterns. In a later interaction, a child assumes the role of a scarecrow with outstretched symmetrical hands, thereby referring to the symmetry in the human body. Still later, the classroom works on patterns of paper folding to define an axis of symmetry. Slowly, the essence of the concept of symmetry is refined through interactions in different modalities and process frames, including conversational interaction, teacher questioning, physical manipulation, and formal definitions. Lesh et al. (2000) also show how children vary markedly in terms of the progression of their understandings of the concept.

Similar developments across time/process frames operate in second language learning. Consider the learning of the distinction in Spanish between the prepositions *por* and *para,* both of which map onto the English preposition *for*. At first, learners with L1 English confuse the two forms. Then the learner picks up a few clear and frequent cases such as *por favor* "please" and *para mi* "for me (benefactive)". As forms with these two prepositions accumulate, instances are compared and grouped to extract higher regularities, such as the use of *por* to indicate motion through space and *para* to indicate the destination, or the use of *por* to express a reason and *para* to express a purpose. Later, these high-level cues can be unified by noting the similarity between reason and motion vs destination and purpose. These further generalizations can arise either with or without overt instruction. The timeframes for these consolidations involve constraints such as noticing usage in the conversational moment, receiving correction, viewing usage during reading, memory consolidation over time, and the slow accumulation of additional examples of each pattern from usage.

Our current analysis seeks to apply the emergentist principles of competition, levels, and time/process frames to account for individual variation in L2 acquisition. Earlier formulations of the emergentist approach to L2 learning (MacWhinney, 2017b) were limited to consideration of the three cognitive factors of entrenchment, transfer, and overanalysis, as well as the social factor of isolation. Here, we present a fuller emergentist theory that includes four motivational dimensions which change systematically with age: a) needs for affiliation and self-actualization, (b) provision of social support, (c) reward immediacy, and (d) resource availability. For each of these dimensions, we also consider in greater detail constraints imposed on the L2 learner from the L1 community.

Along with its more detailed analysis of social and motivational factors, the current exposition links plausible biological mechanisms to their effects on specific linguistic levels. In this regard, it is useful to distinguish single-process accounts for age effects from multiple-process accounts. An example of a single-process biological account is Lenneberg's (1967) claim that the completion of cerebral lateralization terminates L2 learning. This assumes that a single biological process affects all language learning, without regard for variation across the six different structural levels of language. Examples of multiple-process accounts include the system of cascading critical periods proposed by Werker and Hensch (2014) and Singleton's (2005) multiple determinants analysis. These accounts recognize that diverse biological forces can be triggered at successive developmental times across linguistic levels, in accord with key aspects of emergentist theory, such as neuroemergentism (Hernandez et al., 2019) and interactive specialization (Johnson, 2011). The full application of emergentist theory examines ways in which biological, social, and motivational constraints operate across time/process scales for each linguistic level. Patterns on longer timescales emerge from interactions on short timescales. Our account includes this fuller set of determining constraints for levels and a wider survey of time/process frames.

The age when a learner was first exposed to their L2 is a key variable of interest. This is often abbreviated AoA, meaning 'age of arrival' when immigrants are the population being studied. From the viewpoint of L2 learning, what is most important is the other reading of AoA, 'age of acquisition' which could predate arrival in the L2 community or even occur without immigration. When we discuss age effects, we are primarily interested in tracking the effects of age of acquisition, measured as the beginning of active involvement in learning L2. To avoid this terminological collision, rather than using the abbreviation AoA, we will refer to "age effects" on L2 learning.

1.1. Variability in learning

Bilingualism researchers have campaigned to supplement universal generalizations about human language with attention to variability in learning processes and outcomes (e.g., Flege & Bohn, 2021; Titone & Tiv, 2023; Luk & Rothman, 2022). Variability in process and outcome is a fundamental aspect of emergentist perspective. As with protein folding or viral mutation, variability in L2 learning can arise from variation in initial cognitive abilities, timing and type of exposure to L2 input, personal motivation, executive control, social support, resource availability, and the relation of L1 to L2. There is also a great range of variation in snowflake patterns, fingerprint friction ridges, cortical folding, species genetics, mountain range contours, or solar flare periodicity. For all these biological and physical systems, as well as for language itself, variation in patterns arises from the action of diverse constraints across multiple levels and time/process frames (MacWhinney et al., 2014).

Factors contributing to L2 variability also influence L1 abilities in both child (Hazan & Markham, 2004) and adult learners (Dąbrowska, 2019). Not all L1 users can give speeches like Obama, present ultra-clear TED talks, or write like Dostoevsky, as noted by De Houwer (2019). The emergentist perspective expects patterns of variation in the learning of both L1 and L2 based on differences in language learning aptitude (Wong et al. 2013; Hernandez et al. 2015), cognitive processing skills, input quality, input quantity, motivation, and life history.

1.2. Successful L2 learning in childhood

The idea that children acquire languages easily and effortlessly remains a staple of everyday discourse, and even some language researchers endorse this idea (e.g., Kuhl, 2004, p. 831). It is thus important to set out broad principles for when childhood second language learning is broadly successful (i.e., allowing successful communication) and when it is less successful.

The most powerful success story concerns those who immigrate as children (Johnson & Newport, 1989; Birdsong, 2005). We will substantiate reasons for this in later sections, but the short form of our answer is that environmental and social forces converge to support learning of the country's dominant language when immigration occurs in childhood. School attendance supplies many hours a day of L2 exposure from varied speakers, including literacy exposure. Like L1 learners, L2 immigrant children want to be included in the peer group (Lee, et al., 2009). When immigrants are interviewed in adulthood, they often recollect the difficulties they had adapting to the new language (Gaytan et al., 2007; Zhou & Bankston, 1998), but they also emphasize the extent to which they had no alternative to devoting themselves to acquiring L2.

The second success story is for children who grow up using two or more languages regularly in the home or in the community (De Houwer, 2009; Leopold, 1949a, 1949b; Yip & Matthews, 2007). When both languages are used in the home, 75 % of children end up using both languages (De Houwer, 2009; De Houwer, 2020). When one language is in the home, and both languages are used in the community, children also frequently learn both languages. These success stories resemble L1 learning by occurring via immersion, not via classroom instruction. These success stories depend heavily on the rich social support that children receive.

However, neither L1 nor L2 learning by children is effortless. Recordings of early child productions in online corpora such as the Davis corpus of twelve English-speaking children in the CHILDES database (Davis, 2010), demonstrate children's struggles with basic articulatory productions well past age three.

1.3. Effortful and unsuccessful L2 learning in childhood

We describe here four contexts of tlearning that are effortful and where child L2 learning is highly variable and often unsuccessful. These examples of lack of learning during childhood demonstrate a weakness of critical period explanations which portray childhood as a time of heightened ability for language learning.

Classroom foreign language learning in elementary school. Educators and the general public have often promoted the idea that "younger is better" for foreign language learning. As a result, policy makers have pushed to begin foreign language instruction in elementary school (Lambelet & Berthele, 2015). Many school systems in Europe experimented with teaching foreign languages as early as grades 1 or 2. However, the results did not meet expectations. Children enrolled in a foreign language class from age 8 to 14 had no advantage in learning outcomes compared to those enrolled from age 11 to 14 (Lambelet & Berthele, 2015; Muñoz & Spada, 2019). Foreign language classes in elementary school can instill respect for other cultures, and they may provide children with an interest in language learning that sets a foundation for later learning, but classroom instruction does not produce the high levels of language learning observed for naturalistic learning (Jaekel et al., 2022). Those children who do succeed have often relied on interactional inputs from outside the classroom (De Wilde et al., 2020).

First language attrition. Many immigrant children experience successful L2 acquisition at the expense of attrition and loss of L1 (Montrul, 2008). A common example of this is when immigrant children attend school and are immersed in the L2, their new country's majority language, with reduced support for their first language (Hyltenstam et al., 2009; Ventureyra et al., 2004). Families who speak a minority language at home often find it difficult to convince their children to acquire and maintain the family language(s) (Piller & Gerber, 2018). As a result, 25 % of children raised in bilingual families end up speaking only the language of schooling and the dominant culture (De Houwer, 2020). Loss of one of the home languages is greater in children growing up with two languages in the home (including the school language) than in children who hear only a non-school language at home (De Houwer, 2021).

Research on attrition has led theorists to propose that the same maturational mechanisms are responsible for both L1 attrition and L2 success (Bylund, 2009; Montrul, 2008). For example, Montrul (2019 p. 4) proposes that L1 attrition specific to children is evidence of a critical period for language learning, because: "Actual language loss is rare in adults, but it is not in children exposed to the same environmental conditions…" However, as we argue in Sections 3 and 4, child immigrants are not exposed to the same social, motivational, input, and cognitive conditions or constraints as their parents.

An extreme case of attrition is the complete loss of L1 in young adoptees (Hyltenstam et al., 2009; Pallier et al., 2003; Reich, 2009; Ventureyra et al., 2004). This could be understood as an example of the phenomenon of "catastrophic interference" demonstrated in neural nets when the training set switches to a new set of input–output pairs (McCloskey & Cohen, 1989; Zevin, 2012). Much milder attrition occurs for children adopted later in childhood (such as after age 10, Köpke & Schmid, 2004). However, such catastrophic loss of L1 does not occur for older children, as demonstrated most clearly in Schmid's (2012) study of Jewish children who left Germany between ages 11 and 15 and who were adopted into English-speaking families. These children retained German despite having no contact with German for up to 50 years. This increased retention in older children may reflect the role of overall

changes in mental function that occur both before and during puberty (Luna et al 2015; MacWhinney, 2008). Those who immigrate later in childhood may also have had the opportunity to become literate in their L1. Moreover, increasing literacy creates a more interconnected and resonant language system which can then resist attrition (Anderson & Reder, 1999; Karmiloff-Smith, 1981; MacWhinney, 2019a). This allows L1 forms to be smoothly activated and replayed, even in the absence of strong L1 input.

Lack of sufficient exposure. Attending a school in which L2 is the principal language results in strong growth of the L2, due to the extensive hours of exposure, academic requirements, and socialization with peers who speak the majority language. However, if school attendance is irregular and the home language is spoken in the local community, L2 acquisition can be haphazard or partial (Ioup, 1989). Moreover, ongoing exposure to accented forms of L2 in the immigrant community will leave traces of non-native forms in both audition and articulation, as emphasized in Flege's SLM-r model (Flege & Bohn, 2021).

Avoiding a language. Children frequently avoid speaking a language addressed to them if they can communicate using a better-known language (De Houwer, 2020; MacWhinney, 2019a). The main example of this has already been mentioned: attempts to teach children a foreign language in a classroom setting. Children may also resist attending to a language spoken by peers, household help or others in their environment. Typically, this occurs when the amount of exposure to the L2 is limited. This also occurs when the minority L1 language is only spoken at home. In these cases, children may respond to parents' L1 requests using the L2 they have learned at school and from peers (He, 2006; Little, 2022). Our point is that children are strategic learners (Locke & Bogin, 2006). This is at odds with the belief that, *ceteris paribus*, childhood is a period of heightened ability to learn languages (Piller & Gerber, 2018).

1.4. Age-of-acquisition as an organizing variable

Seminal studies on adult immigrants in the 1970s and 1980s documented that the age at which they had immigrated predicted L2 ability years later when tested as adults (Bialystok & Miller, 1999; Chiswick & Miller, 2008; Flege, 1987; Flege et al., 1999; Hakuta et al., 2003; Johnson & Newport, 1989). As a follow-up to this research, DeKeyser et al. (2010) conducted parallel studies in different geographical regions, with Russian immigrants to the US acquiring English, and Russians acquiring Hebrew in Israel. The result was a nearly linear decline in grammaticality judgment scores for immigrants with later age of immigration (Vanhove, 2013). The CPH offers a ready explanation for why age of initial learning correlates with learning outcomes even decades later. However, consistent with the truism that correlation doesn't imply causation, many authors have noted that age of immigration is confounded with other important exposure variables (e.g., Bialystok & Hakuta, 1999; Birdsong, 2005; Marinova-Todd et al., 2000). However, the term 'confounding' is misleading because it implies that age is not the operative factor. The situation is more complex than this, as developmental psychologists have long noted (Wohlwill, 1970). There is a sense in which age *is* causal, because arriving in a new country reliably triggers a host of other factors. One of these occurs when child immigrants are exposed to the majority language in school for hours a day, including exposure to literate practices in L2. One consequence of this is that immigrants' educational level when their L2 is tested as adults is just as strong as the effect of having early exposure to L2 (Hakuta et al., 2003). Flege and Bohn (2021) found that learners with an earlier acquisition age had a much greater daily proportion of exposure to L2. What appears as an effect of early age of learning may also be an effect of overall input.

In summary, age is not a causal variable in its maturational sense, but age is also not merely a confounding variable. It is an organizing variable. It sets into motion and enables diverse social and motivational factors discussed in the following sections.

1.5. Successful second language learning in adulthood

Given sufficient social support and motivation, adults can achieve high levels of proficiency in L2 (Birdsong, 1992; Bongaerts, 1999; Hartshorne et al., 2018; Ioup et al., 1994; Nikolov, 2000; White & Genesee, 1996). The clearest cases of this type involve immigrants who achieve full integration into a new L2 culture because of their profession, marriage, or religion. Evidence for successful adult L2 learning comes from an Internet survey and proficiency test (Hartshorne et al., 2018) which collected data from 2/3 of a million people from around the world. Analysis revealed that a marked drop in L2 learning outcomes only occurs after age 17–18, rather than at the earlier ages stipulated by critical period hypotheses. One explanation for the drop at this age is that opportunities to learn or improve the L2 diminish in adulthood, because adults must focus on work or professional education. Even given pressures for work or higher education, the top 25 % of the learners who began after age 20 achieved proficiency scores within the range achieved by L1 users. Hartshorne et al. note that their results do not conform to any known maturational account of age-related effects.

Although many adult learners acquire highly functional control of L2, they seldom reach a level that is indistinguishable from L1 users. Some researchers interpret this as supporting the CPH. Others emphasize the extent to which bilinguals should not be viewed as two monolinguals, but rather as speakers of systems that interact dynamically with transfer from L1 to L2, as well as from L2 to L1 (Döpke, 2000; Kasparian & Steinhauer, 2017; Liu et al., 1992; Ortega, 2019; Yip & Matthews, 2007). The mutual influence between learners' languages is a key aspect of the competitive mechanisms of emergentist frameworks (e.g., Harris et al., 2001; Hernandez et al., 1994). Often learners may be less concerned with being able to pass as a native L1 user than with being able to communicate effectively (Piller, 2002). Moreover, maintenance of an L1 accent or style can be seen as a mark of ongoing commitment to one's social roots and a mark of personal identity (Dörnyei & Ushioda, 2009; Moyer, 2013).

Even highly proficient adult learners may fail to acquire the more subtle features of L2. An example is using the English article by speakers of languages that do not have articles (Zhao & MacWhinney, 2018). Individual differences may reflect genetic variation in cognitive factors underlying the aptitude for language learning. Examples of such abilities are phonetic-phonemic coding, sensitivity to sequential patterns, and both rote and inductive learning ability (Bylund et al., 2012). In a study of advanced learners of Swedish, language aptitude predicted which learners were sensitive to subtle grammatical features of their L2, and it was a stronger predictor than age of learning (Bylund et al., 2012). Using different methods, Kinsella and Singleton (2014) found that attainment of a high level of L2 control is most clearly linked to integration into the L2 society, suggesting a role for motivation. These findings do not support a role for critical periods in adult L2 learning.

1.6. Unsuccessful and variable second language learning in adulthood

Adults may begin L2 learning with enthusiasm, but their motivation can erode as they gain awareness of the time and effort required to attain proficiency (Cheng, 2016; Dewaele et al., 2023). Is the large effort required itself evidence for the critical period hypothesis? The alternative explanation is that cognitive, motivational, and environmental forces can often block the pathway to successful adult L2 learning. In Section 2 we describe the role of cognitive forces; in Section 3 we examine motivational forces; and in Section 5 we consider the changing role of environmental constraints across the lifespan. Overall, we argue that variations in the success of L2 learning are best attributed to the impact of constraints operating within the dimensions of competition, levels, and timeframes.

2. Cognitive forces in L2 learning

The Unified Competition Model (MacWhinney, 2017b) holds that age-related changes in the success of second language acquisition arise from the operation of constraints on cognitive processes, environmental supports, and motivation. The cognitive constraints include three risk factors and three protective factors to be examined in this section.

2.1. Risk factors

The model identifies three cognitive processes that pose risks or challenges to adult second language learners. These are the risk factors of entrenchment, negative transfer, and overanalysis.

2.1.1. Entrenchment

Entrenchment of linguistic forms arises from repeated use over time (Schmid, 2017) in the service of communicative purposes (Divjak & Caldwell-Harris, 2015). Entrenchment increases automaticity through the proceduralization of cognitive skills (Anderson et al., 2019; Kamhi, 2019) and it improves declarative recall through the strengthening and diversification of semantic links (Schlichting & Preston, 2015). This strengthening relies on a variety of neurodevelopmental processes, including myelination (Pulvermüller & Schumann, 1994), synaptic pruning (Edelman, 1987), long-term potentiation (Hebb, 1949), circuit formation (Pulvermüller, 2003), and inhibition of competitors (Sirosh & Miikkulainen, 1993). Neural nets can be used to model how entrenchment produces L2 age effects (Li & Zhao, 2013; Monner et al., 2013), based on the assumed operation of core neuronal processes. These processes involve a gradual shift between the unformed and plastic infant brain network to the faster and more highly organized adolescent brain. The fact that these changes involve a gradual shift from plasticity to entrenchment aligns well with evidence for a gradual linear decline in ability to acquire full control of L2, as well as the loss of L1 in young adoptees. These various neuronal processes operate across all cognitive domains and require no invocation of any critical period unique to language (Zevin, 2012). Moreover, entrenchment impacts all levels of linguistic structure, although the exact nature of this impact varies across levels, as discussed in Section 5.

2.1.2. Negative transfer

Once entrenched, strong L1 patterns can overwhelm weaker competing L2 patterns. For example, speakers of French have learned to position the adverb after the verb, whereas English speakers have learned to position the adverb before the verb. When an English-speaking learner of French seeks to form an utterance that includes an adverb and a verb, negative transfer can lead them to produce *je souvent vais* "I often go", rather than the correct order of *je vais souvent* "I go often". Researchers refer to this competition between patterns variously as negative transfer, cross-language influence, or interference. Sometimes, there is a close match between L1 and L2 patterns and the transfer is more positive than negative. However, the resemblance can also be deceptively close, making error detection more difficult (Eckman, 2008).

Knowing exactly how L1 and L2 patterns will compete in specific cases involves a theory of transfer that is not yet fully articulated. Lado (1957) and others captured some aspects of transfer in the theory of contrastive analysis, but a fuller elaboration, based on experimental evidence, is still in progress (Yu & Odlin, 2016). The Competition Model holds that competing patterns will trigger some level of negative transfer. However, competition requires an overlap in form or meaning and there are areas in which there is no mapping between L1 and L2. For example, English has very little marking of nominal case and gender. Thus, learning of the German system of case-number-gender marking on the noun phrase is not subject to negative transfer from English. This is not to say that learning is frictionless when there is no negative transfer. On the contrary, the internal complexity of the German system presents a learning challenge quite apart from the issue of negative transfer, involving instead the impact of the risk factor of overanalysis.

The interplay between L1 and L2 has a bidirectional impact. Over time, immigrants' L1 can undergo attrition (Liu et al., 1992; MacWhinney, 2019a; Schmid, 2011; Schmid & Köpke, 2019) stemming largely from the intrusion of L2 patterns onto L1. In the emergentist framework, the dimension of competition emphasizes the ubiquity of such cross-linguistic interactions. The ongoing nature of these effects has been further supported by psycholinguistic studies showing simultaneous co-activation of both languages in bilinguals, even during tasks that require use of only one of the languages (Costa et al., 1999; Kroll et al., 2008; Marian & Spivey, 2003).

2.1.3. Overanalysis

Overanalysis arises when an L2 word is acquired without regard to the phrasal structure in which it is embedded. For example, an English learner of German might hear the phrase *mit der Bahn,* meaning "by train" and only learn that *Bahn* means railway, rather than learning *mit der Bahn* as a meaningful chunk. As a result, the learner misses the cues to feminine noun gender and dative prepositional case-marking contained in the full phrase (Walter & MacWhinney, 2015). Overanalysis plausibly occurs because learners who already have a fluent L1 can understand and communicate in a new language by mapping keywords to their L1 translations. Agreement markings may be ignored (MacWhinney et al., 1984), as well as case marking (Jackson, 2007) and hierarchical structure (Frank et al., 2012). Overanalysis hinders grammar acquisition and may be a serious obstacle to fluency when L1 includes little morphological marking, such as English or Chinese. Learners with an L1 that is more morphologically aligned with the L2 may overanalyze less. Overanalysis can also operate above the phrasal level. For example, learners of Spanish may fail to pay attention to agreement marking (VanPatten et al., 2012) or clitic pronouns (VanPatten, 2011), because these markings require attention to large stretches of input that are not being fully processed.

2.1.4. Pattern recognition

Child language researchers have often emphasized the extent to which children excel in picking up general patterns in morphology (MacWhinney, 1975; 1978), lexicon (Bowerman, 1978), and syntax (Ambridge et al., 2012). In many cases, children surpass adults in their sensitivity to pattern generalization (Newport, 2016). The first experimental demonstration of this occurred when MacWhinney (1983) compared child and adult learning of a miniature linguistic system (MLS). In that study, adults reproduced the statistical patterns in the input, whereas children extracted the dominant regularities. These results provided support for Slobin's (1973) universal operating principle of "paying attention to regularities." The finding was replicated in a similar MLS experiment by Hudson Kam and Newport (2005). In both experiments, children generalized morphological patterns more often than did adults. This resulted in more errors for children, whereas adults successfully learned the frequency distributions. An implication is that adults succeed in avoiding overgeneralizations, but at the expense of weaker pattern-learning. This is in line with the Slavic proverb cited by Jespersen (1933) that "to learn a language you must first break it.".

Parental input composed of short words helps pattern extraction while minimizing demands on children's limited working memory. Examining the Brent corpus of maternal English child-directed speech (CDS) in CHILDES (MacWhinney, 1991), MacWhinney (2014) showed that 23.8 % of the utterances that parents direct to children aged 9 to 15 months involve single words, consistent with the pattern of children's speech during the single-word phase that dominates at this age. Emphasizing single words simplifies the task of segmenting speech. In this way, parents are presenting material that is finely tuned to the child's level of development (Sokolov, 1993; Vygotsky, 1934). However, this form of fine-tuning only lasts until the child can process longer utterances, at which point adult input then shifts to a greater complexity

(Sokolov, 1993).

2.2. Protective factors

The Unified Competition Model identifies four cognitive processes that provide protection or support for adult second language learners. These are the protective factors of resonance, decoupling, chunking, and aptitude. These protective factors serve to counteract the challenges arising from the risk factors. The interplay between risk factors and protective factors involves a fundamental cognitive competition that plays out in different ways across linguistic levels and timeframes.

2.2.1. Resonance

Resonance involves the construction of linkages in long-term memory between L2 forms. The more that L2 words and concepts are linked together, the more they can avoid being dependent or parasitic on L1 forms. Resonance mitigates the negative effects of L1 entrenchment by joining L2 forms in a tighter web of relations to other words or concepts (Fisher, 1992). It also strengthens their direct connections (Kroll et al., 2010) to underlying perceptual features (McClelland & Rogers, 2004), constructions (Culicover, 2013; Goldberg, 2006) and memories (Marian & Neisser, 2000). Earlier memory models treated these associations in terms of the theory of spreading activation (Collins & Loftus, 1975) which continues to play a role in theories of declarative memory. However, that theory is now being supplemented by accounts of consolidation of memories in the hippocampal system (Kumaran et al., 2016; Schapiro et al., 2017). An important component of these newer models is the idea that consolidation is supported by reentrant connections between cortex and hippocampus (Schlichting & Preston, 2015). By focusing on relations between forms, learners can rely on this system of reentrant connections to strengthen semantic links. For example, when learning the Spanish word *obrero* "worker", an English speaker might relate to the Spanish word *obra* "work" and link this to the idea of a "work of art" phrased as *obra del arte*. Also, the learner can link the agentive ending *-ero* to similar forms such *panadero* "baker" or *zapatero* "shoemaker". The more that a learner can reflect on the connections between words and constructions, the richer the set of connections and cues for retrieval and quicker access. A particularly powerful application of resonance involves linking the phonological forms of L2 words to their orthographic forms (Share, 1995) which provides continual resonance between the two systems. Resonance can also be supported through memorization of songs and poems in L2 for which rhythm and rhyme promote retrieval of successive passages.

2.2.2. Decoupling

Decoupling works together with resonance to mitigate the effects of negative transfer and entrenchment. Kroll's Revised Hierarchical Model (Kroll et al., 2010) holds that beginning learners tend to link L2 to meanings indirectly through parasitic linkages to L1 forms. The most productive ways of decoupling L2 from L1 are to engage as much as possible in conversational interaction and, when not interacting directly, to engage in "internal L2 thinking" without shifting back to L1 thinking (Pavlenko & Lantolf, 2000; Vygotsky, 1934). With practice and the right opportunities, learners can work increasingly in the second language without dependence on the first.

2.2.3. Chunking

Chunking involves avoidance of overanalysis and attention to larger phrasal groups (Conklin & Schmitt, 2012). If a learner of German overanalyzes the phrase *Zeitreise ins Mittelalter* "time travel into the Middle Ages", they might only pull out the words *Mittelalter* as meaning "Middle Ages" and *Zeitreise* as meaning "time travel" without attending to the cues to the gender contained in the preposition *ins* "in the". However, the fact that *ins* is used rather than *in dem* reflects the fact that *Mittelalter* is taken as the goal of the *Zeitreise*, rather than a static position. Moreover, the final /s/ of *ins* codes the fact that *Mittelalter* has neuter gender, which is determined by the second part of the compound noun. Unless the learner stores *Zeitreise ins Mittelalter* as a unit for immediate reflection or later analysis, none of this further learning is possible. In general, the more that learners can pick up full phrasal chunks, the more they have access to important aspects of morphosyntax. Of course, very young children and beginning L2 learners cannot pick up full phrases until their vocabulary reaches a certain level. But once it does, they can benefit from chunking. In this sense, rather than "less is more" (Newport, 1990), chunking illustrates how "more is more".

2.2.4. Aptitude

Aptitude predicts successful L2 learning (DeKeyser, 2012; Wen et al., 2017), as well as the retention of L1 in adoptees (Bylund et al., 2010) and switching ability in bilinguals (Claussenius-Kalman et al., 2021; Hernandez et al., 2015). Aptitude measures such as LLAMA (Rogers et al., 2017) examine abilities in adults for lexical, phonological, and morphosyntactic learning. To gain a fuller view of aptitude, we need to link these measures to core cognitive processes such as short-term memory, auditory encoding, task-switching, or speed of lexical access. We also need to better understand whether aptitude arises from individual neurological differences in these skills or from epigenetic shaping through motivation and use.

There is evidence that aptitude can function as a cognitive protective factor for phonological (Perrachione et al., 2011) and lexical (Wong et al., 2012) learning. Wong et al. (2017) survey a number of genetic patterns that could function to support individual differences in language learning. If these accounts can be replicated and extended, they might well provide a mechanistic basis for linking acquisition-age to neurological forces such as the timing of gene expression.

3. Motivational and social forces in L2 learning

The risk and protective factors described above all involve cognitive aspects of second language learning. In this section we analyze the social-motivational constraints that facilitate or inhibit L2 learning (Dörnyei, 2009). We argue that language learning is constrained by the same range of motivations found in wider theories of motivational control (Carver & Scheier, 2019; Murray, 1938). Human needs change across the lifespan, leading to changes in the motivation to invest in L1 vs L2. We identify four factors which change systematically with age: (1) needs for affiliation and self-actualization, (2) provision of social support, (3) reward immediacy, and (4) availability of resources for language learning.

3.1. Needs for affiliation and self-actualization

For infants and toddlers, the need to elicit and maintain connections with caregivers is predominant. This need is a basic part of the human genetic endowment, dubbed the interactional instinct by Lee et al. (2009). This instinct promotes keen attention to adult facial expressions and verbalizations, facilitating both monolingual and bilingual acquisition. Middle childhood brings the need for affiliation with friends, involvement in group play, and support from authority figures. These forces for affiliation impel children who speak a minority language at home to switch their language dominance from the home language to the language of peers and teachers.

Adolescents' growing self-awareness brings with it an increased need for self-actualization (Maslow, 1971). Adolescents may become aware of the impact of ethnic differences and economic benefits (DeVoretz & Werner, 2000), which can promote interest in either L1 or L2 learning. Adults need to protect their hard-won and long-sought status as competent adults in the social hierarchy (Del Giudice & Belsky, 2011). Fumbling with a new language can position the learner as a subordinate. Staying within an ethnic enclave is a functional method to maintain adult status, although it impedes L2 acquisition (Alba et al., 2002). The

search for identity and self-actualization can be a major force motivating commitment to L2 learning (Dörnyei & Ushioda, 2009). Detailed ethnographic studies of individual learners show that those who seek identification with the L2 culture report fuller acquisition (Duff, 2019). At the same time, commitment to the L1 community can impede assimilation of L2 forms. For example, Tunisian men, but not women, pronounce French /r/ as apical [r], rather than uvular [ʁ] to mark their divergence from the French standard (Walters, 2011).

3.2. Provision of social support

Human groups are configured in myriad ways to respond to individuals' needs for affiliation and self-realization. Social groups and institutions support L1 vs L2 learning differently in different situations, at different ages (Jia & Aaronson, 2003). First language learners receive continual support from caregivers for learning via modeling (Waterfall et al., 2010), expansion (Denby & Yurovsky, 2019; Sokolov, 1993), responsiveness (Tamis-LeMonda et al., 2014), and repetition (Schwab & Lew-Williams, 2016). Children learning two languages from birth receive similar support (De Houwer (2021; De Houwer & Bornstein, 2022). The result is that social support for language learning, including bilingual learning, is at its highest point in infancy and early childhood.

A different type of social support that favors L2 learning for immigrants occurs in the preschool years and later, with out-of-home childcare and public schooling. Schooling provides massive amounts of exposure to L2, facilitating its rapid acquisition by immigrant children. With the end of the school years, social support for learning the culture's dominant language drops precipitously. Little social support exists for L2 learning by middle-aged adults and the elderly (Simpson, 2020; Gonçalves, 2019; Singleton & Pfenninger, 2019). Moreover, because of commitments to work and family, adults can seldom spend more than a few hours each week in formal language learning.

Immigrants may be shunned or embraced by members of the dominant culture depending on their ethnic background, a factor that can speed or impede learning the majority language (Anya, 2016). In some cultures, gender identity can influence social support for L2 learning (Pavlenko & Piller, 2008). The success or failure of these various social supports or barriers to affiliation and self-actualization can have a dramatic impact on the outcome of L2 learning.

3.3. Reward immediacy

People (and animals) continuously predict the likelihood of achieving an outcome that confers rewards and satisfies goals (Niv et al., 2012) and language choice is subject to this same pressure. Because of prediction difficulties and opportunity costs, humans and animals discount the value of temporally distant rewards. A result is that immediate rewards are powerful shapers of learning a new language.

Children receive more immediate and concrete rewards than do adults in the early stages of second language learning. The types of social support we mentioned above (modeling, expansion, responsiveness, and repetition) are delivered to children immediately along with a generally positive affect. In contrast, adults' fledgling L2 practice is often met with correction and rejection. In structured classroom settings, adults may receive a high level of corrective feedback, which may be counterproductive in early stages of learning (Long, 2023). The fine-tuned, comprehensible input that is directed at young children brings rewards of goal attainment and social interaction, in contrast with the more opaque conversation encountered by older children and adults.

High intrinsic and extrinsic motivation, including connecting to the culture of the new language (see Al-Hoorie,& MacIntyre, 2019), can compensate for the lack of immediate rewards for adults. Adults may seek to develop proficiency to obtain employment or resources in a new country (DeVoretz & Werner, 2000). Pursuing distant rewards requires steadfast use of executive functions, such as self-talk, planning, and future-time perspective (Ainslie, 2001). The ability to use executive control to set aside smaller-sooner rewards for the larger-later rewards is developmentally more available for older learners. Executive function use is also an individual differences variable, and thus part of the explanation for the higher variability in ultimate outcomes for older vs younger learners.

3.4. Resource availability

Resource availability refers to the quantity and quality of what is available in the environment to support language learning. Young children receive grounded input which can be readily mapped to meaning structures (Bloom, 2000; Merriman, 1999; Tomasello, 2003). The complexity of language in the environment generally increases with age and is thus a powerful determinant of age effects in L2 learning.

Another type of resource availability is the quantity of L1 vs L2 in the environment. Whether the environment includes more L1 or more L2 is influenced by learners' social understanding and physical agency. Children show marked age effects in their selection of peers for play and friendship. Jia and Aaronson (2003) asked children who had immigrated from China between age 5 and 17 whether they spoke Chinese with their peers, and why or why not. Responses differed systematically with age. Children who were between 5 and 9 years old reported minimal use of Chinese, because few children (or in one quote, no children, p. 146) at school spoke Chinese. Children aged 12–13 years reported speaking Chinese with other Chinese-speaking students, and English with children from other backgrounds. The oldest two students, age 15 and 16, specifically sought out L1-speaking peers, consistent with affiliation needs. The authors noted: "The highly developed social abilities of the adolescents enabled them to find L1-speaking friends from various social settings and somewhat distant geographic areas. In contrast, younger children's limited social abilities and parental restrictions on mobility meant that they made friends with others who happened to be physically close" (p. 145). Age of immigration thus influenced social mobility and agency, which then resulted in more L2 resources for those who immigrated in early and middle childhood, and more L1 resources for teenage immigrants.

Resource availability includes access to both formal and informal instruction, textbooks, media, and video games. As we've mentioned, schooling makes the majority language highly available to children. Adult L2 learners need to expend money and travel time to seek out settings in which they are immersed in an L2 environment with a high level of support for L2 learning.

3.5. Adult compensation - protective factors

Consider the four motivational factors of (1) need for affiliation/self-actualization, (2) social support, (3) reward immediacy, and (4) resource availability. These work to support or protect young children's learning, whereas they are risk factors for adults. To compensate for these risk factors, adults need to work strategically to minimize the risk factors in these four ways:

- Those who immigrate as adults can address their needs for affiliation and self-actualization in a variety of ways. One option is acculturation (Al-Hoorie & MacIntyre, 2019; Schumann, 1986), which then opens avenues for L2 learning. However, if a vibrant L1 community is available, this can fulfill an immigrant's needs for both affiliation and self-realization, thereby leading to decreased L2 attainment.
- To maximize the availability of social support, adults can become members of L2 groups. By participating in venues such as churches, sports leagues, or social clubs (Day & Wagner, 2007), adults can maximize language input and support from the L2 community.
- It is unlikely that adults will ever receive the type of immediate and rewarding feedback available to children, but they can use their greater executive control to rely on patience and determination to progress with the task of L2 learning.

- Adults can use their wider access to electronic and printed media to find good resources for L2 practice and learning systems. These resources may be most effective for the development of comprehension, as opposed to production. However, advances in automatic speech recognition (ASR) in the context of online games, lessons, and interactions may soon make online use and training of production a possibility. In addition, as Li and Jeong (2020) have shown, immersive virtual reality (IVR) systems are able to provide adults with the type of embodied learning experiences (MacWhinney, 2008) that are otherwise typically only available to very young children. Studies of the learning effects of these systems (Krokos et al., 2019) have yielded promising results. Moreover, there is evidence that embodied environments activate a broader functional neural network than the one triggered by non-immersive and non-embodied environments (Li & Jeong, 2020; Redcay & Schilbach, 2019).

4. Ages and constraints

We have already mentioned various ways in which motivational constraints vary across ages or timeframes. Here we summarize the effects of these cognitive, motivational, and social factors on L2 learning across the major periods of the human lifespan.

4.1. Infancy and early toddlerhood (ages 0 to 2)

The risk and protective factors outlined above explain why infants and toddlers are outstanding language learners. Affiliative needs, social support, reward immediacy, and resource availability are all at maximal levels. For this age group, learning two languages simultaneously brings none of the risks facing older children or adults. There is minimal negative transfer, overanalysis, or entrenchment. Opportunity costs are close to zero. Control of audition, while not yet perfect, is highly advanced (see Section 5 on levels). Due to their limited executive function abilities, infants have low strategic control, meaning they are less able to opt-out of processing stimuli around them. As a result, they devote much of their attention to incoming stimuli (Kuhl et al., 2003; Lee et al., 2009).

4.2. Early childhood (ages 3 to 6)

During early childhood, children become increasingly strategic (Selman, 1980; Weinert & Perner, 1996). When exposed to three or more languages, children frequently minimize use of at least one of these languages (Zhan, 2021; Mieszkowska et al. 2017). Young children may begin to use the L2 peer language at home, placing them at risk for weaker L1 acquisition (Meng & Miyamoto, 2012; Quay, 2012). On the other hand, when peers at the preschool or community share the child's L1, immigrant children can prefer that language for peer conversation. This could delay L2 learning, although empirical evidence on this is lacking.

Young children may find that low proficiency in L2 marks them as different. This can lead to frustration (Chang et al., 2007; von Grünigen et al., 2012), but it can also fuel learning via a desire to participate. Given the many facilitative factors and absence of strong risk factors, learning a majority language as an L2 in early childhood is usually eventually successful, although the route to proficiency may be lengthy (De Houwer, 2021).

4.3. Middle childhood (ages 6 to 12)

When exposed to a new language in middle childhood, the major difference in constraints compared to earlier ages involve (1) changing social support for participation in the L2, (2) a growth in strategic control, and (3) increased complexity in language input. The onset of compulsory schooling at age 6 provides strong support for learning the majority language. In addition, during middle childhood, L2 learners can benefit from improvements in strategic control (Selman, 1980; Simon, 1990; Weinert & Perner, 1996) that occur during the "five to seven-year-old shift" (Weisner, 1996). Strategic control allows children to learn from a wider variety of situations.

A major challenge of breaking into a new language in middle childhood is the greater complexity of the language being used in elementary school compared to earlier years. Students must learn complex vocabulary, spelling, and grammar. Immigrant children need substantial skills in the dominant language to thrive in the wider social group (Locke & Bogin, 2006). The result of the convergence of these constraints is that children who immigrate during these years will usually, but not inevitably, achieve a high level of proficiency in the new language.

There is some evidence that, given the right opportunities, middle childhood represents a period of heightened opportunity to become bilingual (Krashen et al., 1979; MacSwan & Pray, 2005). What we can call the "immigrant sweet-spot" results from a configuration of four positive cognitive and social/motivational factors for at least some children:

1. L1 entrenchment is strong enough to protect L1 from strong attrition.
2. L1 entrenchment is weak enough to allow L2 learning without severe negative transfer.
3. Peer orientation and immersion in L2 via the school system propel learning of L2.
4. Family attachment and immersion in L1 at home allow continued refinement of L1.

4.4. Adolescence and young adulthood (ages 12 to 20)

Immigrants arriving in mid-to-late adolescence and young adulthood face increasingly heavy cognitive and social/motivational risks, including an increasingly entrenched L1 and deeper cultural commitments to their language of origin. The consolidation and automatization of L1 alters the costs and benefits of L1 and L2 use. Entrenchment of L1 facilitates its long-term maintenance, but produces negative transfer in L2 learning (MacWhinney, 2019a). Some adolescent immigrants can join L2 peer groups, but others may face exclusion (Holmen & Jørgensen, 1997), leading them to join peer groups composed of other immigrant adolescents.

Alongside these risk factors are motivational factors that can either facilitate or impede L2 learning. Adolescents begin to think systematically about their place in a global world (Selman, 1980). Teens can become aware of how national dominance and hegemony can lead to oppression and stigmatization of minority groups, of which they may be a member (Anya, 2016). Adolescents are also in the midst of developing cultural self-identity and a sense of purpose (Damon et al., 2003). Teens' ability to appraise the worth of L2 learning allows them to pursue multiple options, which can be loosely placed into 3 categories.

1. They can strengthen their commitment to the culture of their homeland, remaining L1 dominant (Flege et al., 1997).
2. They can focus on assimilation to the dominant language and culture (Jia & Aaronson, 2003) along with a gradual loss of facility in L1.
3. They can cultivate a bilingual-bicultural persona that emphasizes high levels of attainment in both languages (Bylund et al., 2012).

When researchers measure the L2 abilities of long-term residents who immigrated as adolescents, their abilities are lower, on average, than similar aged persons who immigrated at younger ages. This is apparent in graphs from Vanhove (2013) and others. This lower ultimate attainment for arrival during the teen years has been interpreted as evidence that sensitivity to language input declines during adolescence. We suggest an alternative explanation. Sensitivity to language input remains high, but teens' strategic sense allows them to choose to prefer

and prioritize either L1 or L2, although some may attempt to invest equally in both. When data from multiple learners are averaged, the result is lower L2 abilities compared to immigration in middle childhood. Consistent with this proposal is the wide variability in outcomes during the teen years and beyond. This is especially apparent in the North American study reported by DeKeyser and Larson-Hall (2005) and in results from census data (Chiswick & Miller, 2008; Hakuta et al., 2003).

4.5. Adulthood (ages 20 to 60)

Adult L2 learners face the same (but stronger) cognitive and motivational risks as do adolescent L2 learners. On the cognitive side, adults face increased entrenchment of L1 and an increased proclivity toward overanalysis. On the motivational side, they face even steeper opportunity costs. Adult immigrants need to establish new social and work lives in a new and possibly difficult setting, often while supporting a family. These forces push adult learners into exploiting the skills they have, rather than exploring the environment and acquiring new skills, as described in the "explore/exploit dilemma" (Hills et al., 2015). Exploiting their fluent L1 to maximize networking often entails living with or near others who speak their L1 (DeVoretz & Werner, 2000). This then increases the risk of isolation from exposure to L2. One common solution to these problems is for immigrants to rely on their fluent L1 alongside a minimal-to-medium level of attainment in L2 (Oxford & Shearin, 1994). Adults may also engage in L2 classroom learning to advance control of L2. However, given their commitments to work and family, the available time for classroom learning is often limited to a few hours each week, in comparison to the large amount of classroom exposure available to children and teenagers.

One route to receiving simplified L2 input occurs when immigrants have young children. Young children may come home after school with English on their lips, thus "English-ifying" the household (Caldwell-Harris et al., 2012). Another route is to learn English from bilingual friends on the job, where employment-relevant English phrases can be conveyed along with work advice and American cultural knowledge. However, communication in L1 remains the most efficient way to solidify friendships, itself of high necessity for immigrants (Caldwell-Harris et al., 2012).

For adults, the major support for L2 learning arises from their ability to take strategic control of the protective factors of resonance, decoupling, chunking, and participation (MacWhinney, 2017b). Access to language learning resources and metacognitive understanding can maximize language learning. When these protective factors are in place, along with economic motivation (DeVoretz & Werner, 2000; Pease-Alvarez, 2003), adult immigrants can learn a new language to high fluency. When unusually high social motivation is supplemented by the cognitive protective factors, high proficiency can be obtained (Kinsella & Singleton, 2014). Examples of successes of this type include immigrants to Israel learning Hebrew (Rosenbaum, 1983), players in the Danish women's handball league (Day & Wagner, 2007), and people who had to acquire a new language to optimize their medical treatment (Yerimbetova & Caldwell-Harris, 2013). An even more effective method for achieving a high level of L2 control is to marry into the L2 community. A less frequent, but similar method is to pay for a fluent speaker to practice one's language skills, while also engaging in cooking, commuting, or grocery shopping (Theodorsdottir, 2010).

The result of the convergence of these constraints is that immigrants who begin L2 learning in adulthood vary from virtually no L2 acquisition to language resembling that of L1 users (Kinsella & Singleton, 2014). Variability in language-learning motivation, together with L1 entrenchment, L1-L2 distance, opportunity costs, and low rewards for L2 use, are the keys to understanding this variability in language-learning outcomes.

4.6. The elderly (ages 60 to 90)

Goral (2019) noted that the language abilities of bilingual speakers remain largely stable into old age. However, the elderly achieve less success in L2 learning than any other age group (Goral, 2019). The reason is that elderly foreign language learners face the same risk factors outlined for adults, but with additional risks unique to old age. These additional risks include awareness of limited lifetime ahead, diminution of physical and neurological abilities, and less benefit from language learning for employment. These additional risks can lead to a lessened interest in executing compensatory activities. The one protective factor for the elderly is the greater availability of free time to devote to L2 learning if they are motivated.

5. Constraints and levels

Emergentist linguistic theory emphasizes how language learning and structure is shaped by constraints operating on the language levels characterized by linguistic analysis (Aronoff & Rees-Miller, 2001; Bloomfield, 1961; Harris, 1951; O'Grady et al., 1997). These six levels are audition, articulation, lexicon, morphology, syntax, and conversation or discourse. These levels are subject to different cognitive, social, motivational, and biological constraints leading to different interactions between age of exposure and L2 attainment (Singleton, 2005).

The emergentist framework specifies that the competition between L1 and L2 will be differentially constrained by the timeframes of human development and the levels of linguistic analysis (MacWhinney, 2015). As a result, L2 learning demonstrates variability depending on linguistic levels and timescales, with each combination of these dimensions subject to its own specific set of constraints. In the current section, we discuss variation according to linguistic levels.

5.1. Audition and perceiving speech

Children are born with the ability to distinguish sounds along certain acoustic dimensions, such as the timing of voice onset which provides the contrast between /p/ and /b/, as in *pin* vs *bin*. (Eimas, 1985). Building on this early inborn ability, children tune their auditory apparatus to favor the sounds of the language in their environment (Kuhl et al., 1987), further warping the phonetic landscape (Holt & Lotto, 2010). They are also busy acquiring the phonotactic structure through statistical learning (Saffran & Thiessen, 2003) and segmenting speech through perception of known chunks (Monaghan & Christiansen, 2010).

The precocious nature of auditory learning raises the question of whether this reflects an early critical period for language learning. During infancy, there is a decline in the ability to detect phonemes from other languages (meaning, languages not spoken in their environment. However, this ability begins to return by age 3, and can return even more clearly during adulthood (Flege & Bohn, 2021; Werker, 1995; Werker & Hensch, 2014), providing a problem for single-process critical period theory.

New ideas about the recovery of plasticity are based on experiments in animals (Werker & Hensch, 2014). Molecular triggers to plasticity can shift neural circuits from an immature to plastic state. Monocular deprivation that induces amblyopia in cats provides a concrete biological example of a period of plasticity followed by a sharp loss of plasticity. In this animal model, visual sensory areas rely on inhibitory circuitry to lock in perceptual contrasts; especially important is GABA (gamma-aminobutyric acid), a neurotransmitter which controls nerve cell hyperactivity. Plasticity can later be returned through epigenetic repression of inhibitory genes such as Lynx1 (Ly-6/neurotoxin-like protein 1). Lynx1 modulates acetylcholine receptors to prevent excessive excitation, which also prevents neurodegeneration. These triggers can also be influenced by environmental stimuli (Werker & Hensch, 2014). The radical nature of a return of plasticity can be illustrated in adult rats, in which a natural restoration of critical period plasticity can

be achieved by exposure to a period of pink noise (Zhou et al., 2011).

This work on amblyopia in cats and the return of plasticity provides the foundation for understanding how human auditory system retains enough plasticity to support good L2 auditory learning up to at least early adulthood, thus allowing some L2 adult learners to achieve accurate L2 phonological perception. Plasticity in early adulthood is plausibly facilitated if learners have sufficient exploratory motivation to pay attention to auditory contrasts, and if they have good resource availability. For example, even difficult perceptual contrasts, such as the ability to distinguish between English /r/ and /l/ for L1 Japanese speakers can be achieved through practice (Bradlow et al., 1999; Ingvalson et al., 2012). Later L2 learning (meaning, in middle childhood or the teen years or adulthood) can be supported by processing of lexical contrasts rather than reliance on raw perceptual differences (Archila-Suerte et al., 2012). In these regards, auditory learning of L2 differs from prototypical examples of critical periods effects (Lorenz, 1958; Marler, 1991; Morton & Johnson, 1991).

Critical periods with concrete drop-offs occur in birds during song learning (Konishi, 1995). Song-bird learning has long influenced conceptualization of age effects in L2 learning (Doupe & Kuhl, 1999; Hyland Bruno et al., 2021). Age-effects for L2 learning show no sharp drop-off (Birdsong, 2018) of the type involved in the lockdown of GABA circuitry. For this reason, researchers have pointed to gradual biological processes such as myelination, lateralization, or metabolic decline as the mechanisms supporting age effects. However, these gradual biological processes are not unique to language. These processes are also correlated developmentally with the equally plausible general cognitive effect of entrenchment (Hernandez & Li, 2007; Monner et al., 2013; Zevin, 2012), as well as constraints from the various social, motivational, and cognitive changes surveyed here.

5.2. Articulation

Output phonology or articulation is the linguistic level that shows the strongest age effects. Compared with other linguistic levels, there is greater evidence for a sensitive period leading to the preservation of L1 accent (Scovel, 1988, 2006). Adults often find it difficult to acquire nativelike pronunciation in a second language, even after they have attained high proficiency on the other levels. In some cases, adult immigrants may not want to sound like the L1 users who were born into the majority culture, given that accent is an important marker of personal and national identity (Rindal, 2010; Zuengler, 1988).

The Competition Model views retention of foreign accent (FA) as arising from the combination of two major constraints determining emergent structure on the articulatory level (MacWhinney, 2017). One is the transfer of articulatory gestures from L1. Extensive evidence for this effect and its linkage to perceptual contrasts is provided in the SLM-r model (Flege & Bohn, 2021). Across-the-board transfer from L1 works in terms of helping a beginning L2 learner make quick progress, but it leads in the end to pervasive and persistent mismatches on the phonetic level (Eckman, 2011). The second constraint, which interacts with the first, is that, unlike neurons elsewhere in the cortex, many of the neurons in the motor cortex cannot be rewired, because of their direct connections to the spinal cord (Kakei et al., 1999).

Two neural structures can help L2 learners achieve reconfiguration of articulation. One set of structures involves a second group of neurons in the area of motor cortex closest to prefrontal areas that maintains plasticity (Kakei et al., 1999; Yamamoto et al., 2006). Another source of flexibility relies on the ability of striate cortex to compose new motor combinations (Dominey, 1998). These systems rely on practice and mismatch signals to acquire new L2 articulatory patterns that are often constructed from pieces of the earlier L1 gestures. However, older learners may find it difficult to focus on the low-level articulatory and auditory details needed to control this reconfiguration (Guenther & Perkell, 2003). Even minor amounts of hearing loss can further exacerbate this problem. If adults have access to tutors with expertise in phonetic analysis, they can improve their L2 articulation, eventually leading to nativelike pronunciation (Derwing et al., 1998).

Flege's original SLM model (Flege et al., 1999; Guion et al., 2000; Munro et al., 1996) linked age-related effects in articulatory development to possible critical period effects. Flege and colleagues asked L1 speakers to judge whether speakers had nativelike pronunciation of certain segments. They found that, for Italian immigrants to Canada, after age 6, few learners acquired a fully nativelike pronunciation. However, there were four effects that went against a critical periods account. First, the amount of FA showed a smooth linear increase with increased age-of-acquisition, rather than the discernable dropoff predicted by many critical period accounts. Second, some of the learners who arrived before age 4 retained a noticeable level of FA. Third, estimation of the amount of L2 input the learner had experienced accounted for variance in FA just as well as age-of-acquisition. Fourth, there were further observed declines in reduction of FA after age 24 which would not be envisioned by a critical period account.

Flege and colleagues noted that the earlier these immigrants arrived in Canada, the more they reported using English and the less they reported using Italian (Flege, 1995; Flege et al., 1997). Most Italians who arrived in Canada between the ages of 5 and 15:

- were soon enrolled in local schools where English was used as the language of instruction,
- learned English from teachers and peers who were L1 users of English, and
- developed lifelong friendships, including marriage, with L1 users of English.

In comparison, the Italian immigrants who arrived in Canada after about the age of 15 had different experiences and outcomes learning English.

- Most males worked outside the home, usually with other Italians who spoke English with an Italian accent.
- Since most females worked at home, their first model of English was typically the Italian-accented English spoken by their male relatives.
- Women had a significantly worse pronunciation than men.

Although late learners of an L2 typically retain an accent, learners can attain accents similar to L1 users when they have high quality input, instruction, and high motivation, and when L1 and L2 are typologically similar (Bongaerts, 1999).

5.3. Lexicon

Older learners, particularly young adults, can acquire L2 lexical items far more quickly than children (Asher & Price, 1967; MacSwan & Pray, 2005; Snow & Hoefnagel-Hohle, 1978). Advantages for older learners include the ease of accessing translation equivalents, as well as positive transfer for cognates and derivations. Lexical items are stored in a distributed system in temporal cortex along with additional connections to other areas of cortex (Gow, 2012). Unlike the systems for audition and articulation, the structure of this system is highly plastic. For example, even when stroke damages large areas of the posterior language regions, aphasics can recover their naming ability through relearning and the use of remaining pathways (Holland et al., 1985).

Children have a different set of advantages in lexical learning relative to older learners. Children have a larger inventory of chunked complex forms, relative to adults. Children also hear less abstract language than do adults, meaning they can more often attach concrete referents to newly learned words. Using fMRI activation and connectivity analyses, Zhang et al. (2020) showed that L2 nouns and verbs triggered weaker activation of related sensorimotor regions compared to L1 words. L1 words are involved in a wider network of co-activation of neural areas (Lambon Ralph et al., 2017). Hernandez and Li (2007) contend that

words acquired by older L2 learners are not be as fully linked to embodied experience as those acquired during L1 learning, in line with models from Kroll (2010) and Li et al. (2007).

5.4. Morphology

Adult learners often have trouble learning to use morphological markings correctly. The two major risks for adult learning of morphology are overanalysis and negative transfer (MacWhinney, 2017b). Overanalysis (Section 2) may be induced by reliance on learning from vocabulary lists. Adult learners may ignore morphological markings and functor items, such as clitic pronouns, because their inferential skills can activate a plausible meaning based solely on content words. Even when function words are noticed, learners may fail to link them to the correct to the correct markers for features such as case, gender, and number, and they may therefor omit function words from their own productions (Montrul, 2010). Child learners, on the other hand, tend to process sentences and constructions as wholes, pulling in the clitics in their correct form along with the rest of the sentence (Pérez-Leroux et al., 2011).

The second risk for adult learning of morphology involves negative transfer from L1. Negative transfer impairs the learning of the function of L2 morphological markings, not their form. An example of this effect is the learning of English past tense marking by German speakers. In English, past tense is marked by a single verb as in *Bill went home*. German can also mark the past with a single verb, but more frequently uses the present perfect, as in *Willi ist nach Hause gegangen,* to emphasize the completion of the action which then implicitly places it into the past. This semantic mismatch between German and English causes errors in aspect marking in L2 English (Cheung et al., 2011; Roberts & Liszka, 2013). The risk of negative transfer increases with age as L1 becomes more cognitively entrenched, resulting in age effects for learning the functions of morphological markings.

An example of a combination of these two risk factors occurs in *María le dió el reloj a Juan* (literally: Mary him gave the watch to John). The clitic pronoun *le* marks the recipient, but it is also marked redundantly in the prepositional phrase *a Juan* (to John). Due to both redundancy and the negative transfer from English word order, English-speaking learners may ignore clitics. Together, these two risks lead to weakness in adult learning of L2 morphology. Neither of these risks arise from any biologically based critical period. Rather they arise from interference and the ways in which adult learners approach the language learning task. These deficits can be corrected through training that focuses on thorough noticing and processing of example sentences (Presson, Davy, et al., 2013; Presson et al., 2014; Presson, Sagarra, et al., 2013; VanPatten, 2004).

5.5. Syntax

Strong age effects occur for knowledge of L2 syntax (DeKeyser, 2000; Johnson & Newport, 1989). Theorists have used this to argue for critical period effects on syntax learning. For example, the Shallow Structure Hypothesis (SSH) (Clahsen & Felser, 2006) proposes that adult learners can only construct a superficial grammatical analysis of input sentences without full hierarchical structure. This hypothesis is consistent with L2 learners' difficulty with complex syntactic structures such as wh-questions and relative clauses. However, L2 learners do not invariably plateau in their knowledge of syntax (Han, 2013). With consistent exposure and motivation to learn, they increase their processing accuracy and speed for diverse syntactic structure (Mitsugi & MacWhinney, 2016). In recognition of this, Clahsen and Felser (2018) revised the SSH to emphasize the gradual nature of the acquisition of syntactic processing abilities in adult L2 learning.

The primary risk factor for syntactic learning is negative transfer from L1. The serial nature of sentence construction makes it difficult to avoid noticing word order during comprehension. In languages such as German or Hungarian where word order is not as reliable a cue as case marking or agreement, Competition Model studies (MacWhinney et al., 1984; MacWhinney et al., 1985) have shown that children aged 3 to 5 rely on word order despite its lower cue validity. This is also true for L2 learners who may rely first on simple word order templates (Gass, 1987) and only pick up more complex patterns over time, even when using incorrect syntactic patterns.

Why does syntactic knowledge demonstrate a stronger age effect than L2 lexical learning? An intriguing proposal is that the procedural aspect of syntactic knowledge relies on the basal ganglia, which may decline in plasticity at a more rapid rate than does the declarative system used in word learning (Hernandez & Li 2007; Ullman, 2004). How rapidly plasticity declines in the procedural system is controversial and some research demonstrates ongoing ability to acquire new procedures and skills (Dominey et al., 2006; Dominey, 1998).

For both morphology and syntax, it is important to distinguish age effects in production from age effects in comprehension. In comprehension, learners can extract meaning by attending to content words and using top-down processing to infer meanings and syntactic structures. Morphosyntactic deficits may have minimal impact on real-life comprehension, even when observable in grammatical judgment tasks (Johnson & Newport, 1991) and Competition Model sentence interpretation tasks in which cues are placed in conflict (Bates & MacWhinney, 1981). For production, on the other hand, learners must control the details of morphology and syntax accurately to avoid errors, thereby more clearly exposing deficits in learning. This problem is particularly difficult for learners of L2s that have complex systems of morphological marking.

5.6. Conversation

A variety of analyses (Goodwin, 2013; Hopper, 2015; Myles; 2015) view conversation as the original locus for the emergence of language structure. Within conversation, we can discern the further organizational dimensions of conversational sequencing (Schegloff, 2007), preference management (Karniol, 2010), speech acts (Searle, 1976), common ground (Clark, 2015), perspective (MacWhinney, 2005, 2008), narrative (Bruner, 1991), and argumentation (Burke, 1969). Each of these systems includes its own principles and patterns to be learned, and all are fundamentally embedded within conversational interactions. The basic principles of conversational interaction are similar across languages (Brown & Levinson, 1987; Ochs et al., 1996), leading to positive overall transfer effects. However, the specific lexical forms and norms used in each language are tightly linked to the rules of the culture and must be acquired during the process of cultural learning.

Learning conversational patterns is largely free of strong age effects. Once learners observe a conversational or social pattern, they can pick it up at any age. Initially, L2 learners may make heavy use of L1 forms for expressing interest, amazement, disbelief, or questioning, as in words such as *sure*, *well*, *but*, *perhaps*, *wow*, *okay*, and *please* (Gardner & Wagner, 2005). Eventually, these functions are mapped onto their L2 equivalents. L2 learners may be slower to learn more complex conversational patterns for requests and politeness, because of lack of exposure resulting from social isolation or conflict with their own interactional style. Child L2 learners, on the other hand, are likely to be surrounded by L1using peers who make use of simpler conversational forms. Furthermore, participation in the typical peer activities of childhood provides intensive conversation practice.

6. The way forward

L2 acquisition is shaped by risk and protective factors that vary across the six levels of linguistic structure, the age of the learner, competition between L1 and L2, and the cognitive and motivational constraints that vary across these levels and timeframes. According to this emergentist account, age effects in second language acquisition are

not a result of the closing of a sensitive period. Rather, they reflect differential effects of cognitive, motivational, biological, and social constraints across the lifespan and linguistic levels. Previous emergentist accounts (MacWhinney, 2017b; Zevin, 2012) have focused primarily on cognitive mechanisms. Here, we have illustrated how emergentism can be extended to incorporate motivational and social forces that help to further explain the variability in age effects for L2 acquisition.

Theorists have urged language researchers to use and develop frameworks for incorporating multiple factors into their language acquisition models (Titone & Tiv, 2023; Luk & Rothman, 2022). There is a need to examine the full set of constraints, levels, and timeframes in L2 learning. Even within a given learner group, we need to consider the impact of individual differences in personalities, cognitive abilities, cognitive styles, strategic choices, motivational preferences, social supports, instructional formats, family structures, economic patterns, and language backgrounds (Titone & Tiv, 2023).

Given the complexity of this system, we cannot yet propose a full mechanistic account of how age of learning determines eventual proficiency and usage outcomes. However, researchers in the emergentist and usage-based traditions have provided quantifiable predictions for different pieces of this puzzle. We have briefly reviewed some of these, including the role of transfer and cue validity in the Competition Model (Liu et al., 1992; MacWhinney, 2017b; Odlin, 2022; Yu & Odlin, 2016), the development of entrenchment in neural network models for L2 (Li & Zhao, 2013), the impact of fine-tuning on child language learning (Sokolov, 1993), and the differential impact on neural structure of lexical learning in L1 vs L2 (Lambon Ralph et al., 2017; Hernandez & Li, 2007; Zhang et al., 2020). Quantified evaluations of predictions exist in these subcomponents of L2 learning, but we are not yet ready to integrate them into a more dynamic integrated whole. Moving in that direction requires a revolution in data collection from ongoing language learning events occurring at different units of time across the lifespan, not just measures of ultimate attainment. DeKeyser (2013) reviews the need for improvements in sampling across a wider variety of learner groups and types, improvements in measurement instrumentation, and increased reliance on computation modeling. Remarkable recent advances in audio and video recording methods, neuroscience, sensor technology, and data science place this revolution within our reach. In this final section, we describe how to move forward toward a mechanistic, emergentist account.

Fields such as Geology, Ecology, Evolutionary Biology (West-Eberhard, 2003) and planetary formation (Beuther et al., 2014) depend on data sets that illustrate dynamically interacting variables across multiple timeframes and process scales (MacWhinney, 2015, 2019b). Methods like these can be applied to L2 learning. Child language researchers have begun to collect daylong recordings in the home (Gilkerson et al., 2017), many of which have been made publicly available at homebank.talkbank.org (VanDam et al., 2016). These have been used for dozens of analyses of the contour of early parent–child interactions. At the time/process frame of seconds, we can look at changes in L2 fluency through studies of pausing, retraced false starts, and other hesitation phenomena, using acoustic and phonological analysis through Praat (Boersma, 2001), Phon (Rose & Hedlund, 2021) and profiling tools from FluencyBank at fluency.talkbank.org. However, to fully understand the constraints on learners, we need to apply these methods longitudinally to detect major dynamic shifts in L2 skills (Eskildsen, 2012; Evans & Larsen-Freeman, 2020).

The increased globalization of the economic, social, and environmental challenges facing our planet entails that understanding and supporting L2 learning and multilingualism is more important than ever. We suggest using and developing further at least nine methodological approaches, some new and some traditional.

1. **Neuroscience**. Advances in neuroscience regarding mechanisms of cortical plasticity (Werker & Hensch, 2014) and memory formation (Ullman, 2004) can facilitate understanding variations in language processing. Comparisons of L2 speakers from different backgrounds or with different language pairings (Kim et al., 2017; Kim et al., 2016) can demonstrate effects of variations in risks and supports across development. Although comparing L2 speakers with monolinguals must be done with care (De Houwer, 2019; Rothman, et al., 2022), they can also be illuminating (Birdsong & Gertken, 2013; Flege & Bohn, 2021; Zhang et al., 2020)
2. **Immersive learning.** Instrumental analysis of recordings of language learning in naturalistic contexts, including immersive virtual reality, can guide construction of ways to compensate for the barriers faced by adult learners (Li et al., 2007; Li & Jeong, 2020; Hamilton & Huth, 2020; Redcay & Schilbach, 2019).
3. **Smartphones**. Modern smartphone technology can track actual patterns of language use for immigrants arriving at different ages immersed in different contexts (Flege & Wayland, (2019).
4. **Measures of motivation**. Smartphone monitoring, questionnaires, analyses of online discussion forums, and laboratory experiments can provide fine-grained measures to understand the risk and protective factors for learning and L2 and for retraining ability in an L1.
5. **Web surveys.** Web surveys can amass large amounts of data regarding variation in language learning experiences, motivations, and outcomes across the globe (Hartshorne et al., 2018; Li et al., 2006). These can be linked with online measures of language fluency, such as those at https://transparent.com/language-resources/tests.html.
6. **e-CALL**. Experimentalized computer assisted language learning (e-CALL) methods (MacWhinney, 2017a) can assess the ability of learners at various ages to acquire new forms and items across each of the linguistic levels and in connected discourse.
7. **Corpora**. We can analyze dense longitudinal corpora, such as those in sla.talkbank.org (MacWhinney, 2021b) to study the learning methods of individual immigrants in specific contexts.
8. **Comprehension**. The methods described above tend to focus on language production. We also need to assess changes in comprehension across L2 development at the lexical, sentential, and narrative level. We can do this using some of the same online measures used for e-CALL.
9. **Models**. Computational simulations and machine learning methods can capture the interplay of constraints in naturally occurring language use, unfolding across time (Li et al., 2007).
10. **Data-sharing**. To take full advantage of these new methods, scientists need to commit themselves more fully to Open Science (Vicente-Saez et al., 2020) and data-sharing of corpora (MacWhinney, 2021b), instruments and their outcomes (Marsden et al., 2016), online data collection (MacWhinney, 2017a), and neuroimaging results (Markiewicz et al., 2021).

Marshalling together data from these comparisons, we can trace the interlocking effects of the many constraints on and facilitators of instructed and uninstructed second language acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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