CHAPTER 14

A unified model of first and second language learning

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The Unified Competition Model views first and second language learning as depending on a shared set of socio-cognitive processes. Differences between the two types of acquisition depend not on the expiration of a critical period, but on the operation of the risk factors of entrenchment, transfer, overanalysis, and isolation. Entrenchment is a neural process that arises from ongoing use of L1 across years. Transfer and parasitism arise from the dominance of L1 during initial L2 learning. Overanalysis stems from the tendency of adult learners to focus on content words, rather than phrases. Isolation arises from the tendency over time for L1 groups to reject the participation of out-group members and from increasing demands for the L1 group. These risk factors can be countered through the processes of resonance, decoupling, chunking, and participation that are available to all learners, but which must become sharpened to promote L2 acquisition.

Keywords: Competition Model, second language learning, critical period, entrenchment, overanalysis, transfer, social factors

1. Introduction

In his landmark study of the biological foundations of language, Lenneberg (1967) postulated a Critical Period for the acquisition of language that would terminate as a result of cerebral lateralization at puberty. Neuroimaging work conducted since then has shown that lateralization is already present at birth (Molfese, Freeman & Palermo 1975) and that it increases during the first two years of life (Mills, Coffey-Corina & Neville 1997). Although researchers no longer link age effects to lateralization, there is still widespread interest in the idea of a Critical Period (DeKeyser 2000) as a way of explaining age-related decline in the outcome of second language learning. However, without any demonstrable link to some specific epigenetic (Waddington 1957) mechanism, and without a sharply defined time for expiration,

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the application of the concept of a Critical Period to language learning lacks the requisite biological underpinnings.

To avoid this problem, Bley-Vroman (2009) has proposed that we can think of age-related decline in second language learning as reflecting a fundamental difference between learning languages in childhood and learning them in adulthood. This Fundamental Differences Hypothesis (FDH) loosens the link of age-related changes to any specific genetic determination. Empirical support for the FDH has come from studies, focused on specific language skills and periods, that detect major decrements in adult L2 learning (Birdsong 2005; DeKeyser 2000; Flege, Yeni-Komshian & Liu 1999; Johnson & Newport 1989; Kuhl 2010). There is no doubt that certain language learning abilities decline with age. However, the course of this decline is uneven (Werker & Tees 2005) and seldom marked by precipitous declines (Hakuta, Bialystok & Wiley 2003). Moreover, it is difficult to reconcile the existence of cases of completely successful second language learning in adulthood (Bongaerts 1999) with the notion of a fundamental difference. There are many adult learners who fail to achieve native-like proficiency, despite years of exposure, but this divergence mostly involves retention of an L1 accent, rather than inadequate ability to comprehend and communicate.

The Unified Competition Model or UCM (MacWhinney 2012) takes a very different approach to this issue. Instead of trying to isolate fundamental differences, the UCM attributes age-related variation in language learning to the interplay between risk factors and support processes. For L2 learning past early childhood, the model postulates the four risk factors of entrenchment, transfer, overanalysis, and isolation. To overcome these four risk factors, adults can rely on the four support processes of resonance, decoupling, chunking, and participation. These processes will be described in detail in Section 2 below. The UCM holds that all of these risk factors and support processes are available to both children and adults. In that sense, there is no fundamental difference between children and adults as language learners. What differs between language learning in childhood and adulthood is the way in which risk and support processes are configured.

Despite these similarities at the level of fundamental processes, there are four obvious differences between child and adult language learners. First, during the process of first language learning, infants are also engaged in learning how the world works. In contrast, adult second language learners already have a basic understanding of the world and human society. Second, infants are able to rely on a brain that has not yet been fully committed to specific tasks (Li, Zhao & MacWhinney 2007). In contrast, adult second language learners have to deal with a brain that has already been dynamically configured for the task of processing the first language. Third, infants can rely on an intense system of social support from their caregivers (Snow 1999). In contrast, adult second language learners are often heavily involved in L1 social and business commitments that distract them from L2 interactions. Fourth,

children have not yet developed adult-like methods for executive control of attention. Although the executive control areas of the brain are active at birth (Doria, Beckman, Arichi & Merchant 2010), they continue to develop through childhood and adolescence (Asato, Terwilliger, Woo & Luna 2010; Casey, Giedd & Thomas 2000). Regularity and inhibitory control over behavior increases in complexity and refinement across the whole period of childhood and adolescence (Munakata, McClelland, Johnson & Siegler 1997). To the degree that language and language learning depend on executive control, we can expect differences between adults and children from these sources, although there is no sharp transition at any point.

Along with these four areas of difference, there are many shared features between L1 and L2 learners. Both groups try to learn the same target language; both need to segment speech into words; both need to learn the meanings of these words; both need to figure out the patterns that govern word combination in syntactic constructions; and both have to interleave their growing lexical and syntactic systems to achieve fluency. Thus, both the overall goal and the specific subgoals are the same for both L1 and L2 learners. In addition, the neurocognitive mechanisms available to solve these problems are the same for the two groups. Both rely on episodic memory to encode new forms and chunks; both have access to embodied encodings of actions and objects; both use statistical learning and generalization to extract linguistic patterns; and both solidify knowledge through routine and practice. Both groups are enmeshed in social situations that require a continued back and forth communication, imitation, and learning, as well as understanding with respect to shared intentions and common ground. One could recognize the shared nature of all those mechanisms and processes, but still claim that the remaining differences are fundamental (Bley-Vroman 2009). The question is whether those remaining differences are great enough to motivate two separate theories for learning and processing. The thesis of the UCM is that the inclusion of L1 and L2 learning in a single unified model produces a more coherent and insightful analysis. The fact that L2 learning is so heavily influenced by transfer from L1 means that it would be impossible to construct a model of L2 learning that did not take into account the structure of the first language. Unless the two types of learning and processing share virtually no important commonalities, it is conceptually simpler to formulate a unified model within which the specific areas of divergence can be clearly distinguished from the numerous commonalities.

2. Three frameworks

The classic version of the Competition Model (Bates & MacWhinney 1982; MacWhinney 1987) was designed to account for the end state of first and second language learning, but not the details of the learning process. As a result, it could

not explain how proceduralization leads to increases in fluency and the avoidance of fossilization. This classic model also failed to incorporate information from our continually growing understanding of the neuroscience of language. Furthermore, it provided no role for social processes in second language acquisition. The UCM works to close these gaps while maintaining the core concepts of competition, cues, cue strength, and cue validity developed in the original Competition Model. To achieve this, it integrates the three frameworks that constitute the theoretical core of the Emergentist Program (MacWhinney & O'Grady 2015): competition, structural analysis, and timeframes.

2.1 Competition

Competition is fundamental to biological processes. Darwin (1859) showed how the evolution of a species emerges from operation of proliferation, competition, and selection. Proliferation generates variation through mutation and sexual recombination. Organisms with different compositions then compete for resources or rewards such as food, shelter, and the opportunity to reproduce. The outcome of competition is selection through which more adaptive organisms survive and less adaptive ones disappear. Language development and change are governed by these same three Darwinian principles.

In population genetics, selection operates through the dispersion of genetic patterns. In language, it operates in terms of the solidification of patterns of cues and cue strengths. We can illustrate this by looking at the ways in which cues compete for thematic role assignment in sentences with transitive verbs. For example, in the sentence *the boys chase the ball*, the two nouns (*boys* and *ball*) are possible candidates for the role of the agent or subject of the verb. However, the candidacy of *the boys* for this role is favored by three strong cues – preverbal positioning, subject-verb agreement, and animacy. None of these cues favors the candidacy of *ball*. Therefore, native speakers uniformly conclude that *the boys* are the agents. However, in certain ungrammatical sentences, the competition between the noun phrases can become tighter. The ungrammatical sentence **the ball are chasing the boys* illustrates this effect. In this sentence, the strong cue of preverbal positioning favors *the ball* as agent. However, the cues of subject-verb agreement and animacy favor *the boys* as the agents. Given a competition of this type, listeners are often quite unsure which of the two noun phrases to choose as agent, since neither choice is perfect. As a result, listeners, as a group, are slower to make this choice, and their choices are nearly evenly split between the two possibilities.

Competition Model experiments use sentences in which cues have been randomly combined to measure the strength of the underlying cues. Typically, the subject's task is to determine which of two or more nouns in the sentence is the

actor. This basic sentence interpretation method has been used in 52 empirical studies involving 18 different languages. The predictions of the model have also been tested using self-paced reading, eye-movement monitoring, ERP, fMRI, and crossmodal priming methods. Across these various experiments and languages, the cues involved come from a very small set of linguistic devices. Languages mark case roles using five possible cue types: word order, case marking, agreement, intonation, and verb-based expectations. For simple transitive sentences with two nouns and a verb, the possible word orders are NNV, NVN, and VNN. In addition, the marking of the cases or thematic roles of nouns can rely on affixes (as in Hungarian or Turkish), postpositions (as in Japanese), prepositions (as in Spanish), or articles (as in German). Agreement marking displays correspondences between the subject and the verb (as in English) or the object and the verb (as in Hungarian and Arabic). Some of the features that can be marked through agreement include number (as in English), definiteness (as in Hungarian), gender (as in Arabic), honorific status (as in Japanese) and other grammatical features. Intonation is seldom a powerful cue in thematic role identification, although we have found that it plays a role in some non-canonical word order patterns in Italian and in the topic marking construction in Hungarian. Verb-based expectations vary markedly across verb types. High activity transitive verbs like *push* and *hit* tend to serve as cues for animate agents and inanimate patients. Stimulus-experiencer verbs like *amaze* and *surprise* cue animate patients and either animate or inanimate agents.

Competition Model experiments put these various cues into systematic conflict using orthogonalized analysis of variance designs. The extent to which cues dominate or control the choices of agent nouns in these experiments is the measure of their *cue strength*. The core claim of both the classic and unified versions of the Competition Model is that cue strength is determined by cue validity. Cue strength is defined through experimental results; cue validity is defined through corpus counts. Using conversational input data such as those available from the CHILDES <http://childes.psy.cmu.edu> or TalkBank <http://talkbank.org> corpora, we can define *cue reliability* as the proportion of times the cue is correct over the total number of occurrences of the cue. Cue *availability* is the proportion of times the cue is available over the times it is needed. The product of cue reliability and cue availability is overall *cue validity*.

Early in both L1 and L2 learning, cue strength is heavily determined by availability, because beginning learners are only familiar with cues that are moderately frequent in the language input (Matessa & Anderson 2000; Taraban & Palacios 1993). As learning progresses, cue reliability becomes more important than cue availability. In adult native speakers, cue strength depends entirely on cue reliability. In some cases, we can further distinguish the effects of *conflict reliability*. When two highly reliable cues conflict, we say that the one that wins is higher in conflict

reliability. For example, in the case of Dutch pronouns, only after age 8 do L1 learners begin to realize that the more reliable cue of pronoun case should dominate over the more frequent, but usually reliable, cue of word order (McDonald 1986).

When adult native speakers have sufficient time to make a careful decision, cue strength is correlated at levels above 0.90 with cue reliability. However, when cue strength is measured online during the actual process of comprehension, before the sentence is complete, other factors come into play. During online processing, listeners tend to rely initially on a single cue with good reliability and high availability without integrating the effects of that core cue with other possible cues. This happens, for example, during online processing of sentences in Russian (Kempe & MacWhinney 1999). Cue strength is also heavily influenced during the early phases of learning by the factors of *cue cost* and *cue detectability*. Cue cost factors arise primarily during the processing of agreement markers, because these markers cannot be used to assign thematic roles directly. For example, in an Italian sentence such as *il gatto spingono i cani* (lit. the cat push the dogs), the listener may begin by thinking that *il gatto* is the agent because it occurs in preverbal position. However, because the verb *spingono* requires a plural subject, it triggers a search for a plural noun. The first noun cannot satisfy this requirement and the processor must then hope that a plural noun will eventually follow. In this example, the plural noun comes right away, but in many cases it may come much later in the sentence. This additional waiting and matching requires far more processing than that involved with simple word order or case marking cues. As a result of this additional cost for the agreement cue, Italian children are slow to pick it up, despite its high reliability in the language (Bates, McNew, MacWhinney, Devescovi & Smith 1982).

Cue detectability factors play a major role only during the earliest stages of learning declensional and conjugational patterns. For example, although the marking of the accusative case by a suffix on the noun is a fully reliable cue in both Hungarian and Turkish, 3-year-old Hungarian children show a delay of about 10 months in acquiring this cue when compared to young Turkish children. The source of this delay seems to be the greater complexity of the Hungarian declensional pattern and the weaker detectability of the Hungarian suffix. However, once Hungarian children have "cracked the code" of accusative marking, they rely nearly exclusively on this cue. Because of its greater reliability, the strength of the Hungarian case-marking cue eventually comes to surpass the strength of the Turkish cue.

Although Competition Model experiments have focused on the issue of thematic role assignment in simple transitive sentences, the principle of competition applies to all areas of sentence processing (MacDonald, Pearlmutter & Seidenberg 1994; MacWhinney 1987). For example, in a sentence such as *the women discussed the dogs on the beach*, there is a competition between the attachment of the prepositional phrase *on the beach* to the verb or the noun *the dogs*. In this case, the competition can be resolved either way. However, in a sentence such as *the*

communist farmers hated died, the competition between the adjectival and nominal reading of *communist* is initially resolved in favor of the adjectival reading, because of the presence of the following noun *farmers* and then the verb *hated*. However, once the second verb is encountered, the listener realizes that the adjectival reading has taken them down a garden path. At that point, the weaker nominal reading of *communist* is given additional strength and the alternative reading is eventually obtained.

Three decades of work with child and adult monolinguals and second language learners across 18 languages within this framework have yielded the following empirical generalizations:

> When given enough time to make a careful choice, adults assign the role of agent to the nominal with the highest cue strength.
>
> When there is a competition between cues, the levels of choice in a group of adult subjects will closely reflect the relative strengths of the competing cues.
>
> When adults are asked to respond immediately, even before the end of the sentence is reached, they will tend to base their decisions primarily on the strongest cue in the languages, essentially ignoring the presence of all the weaker cues.
>
> When the strongest cue is either missing or neutralized by being coded on two separate nominal phrases, the next strongest cue will dominate.
>
> The fastest decisions occur when all cues agree and there is no competition. The slowest decisions occur when strong cues compete.
>
> Children begin learning to comprehend sentences by first focusing on the most available cue in their language.
>
> As children get older, cue strengths converge on the adult pattern with the most reliable cue growing most in strength.
>
> As children get older, their reaction times gradually get faster in accord with the adult pattern.
>
> Compared to adults, children are relatively more influenced by cue availability, as opposed to cue reliability.
>
> Cue strength in adults and older children (8–10 years) is not related to cue availability (since all cues have been heavily encountered by this time), but rather to cue reliability. In particular, it is a function of conflict reliability, which measurs the reliability of a cue when it conflicts directly with other cues.
>
> Past the first years of childhood, learners tend to transfer cue strengths from L1 to L2.

A bibliography of 142 studies supporting these conclusions can be found on the web at <http://psyling.psy.cmu.edu/CM-bib.pdf>.

2.2 Structural analysis

Complexity arises from the hierarchical recombination of small parts into larger structures (Simon 1962). For language, the smallest parts are the articulatory commands of output phonology, the auditory features of input phonology, and the perceptual features underlying semantics. These articulatory and auditory patterns combine into words that combine into phrases that combine into mental models that compose interactions and narratives. Within each of these major structural levels, we can distinguish additional substructures. Within phonology, words are structured into tone groups composed of syllables that are composed of onsets, nuclei, and codas, which control clusters of articulatory gestures. Within the lexicon, morphemes can be combined into compounds, phrases, inflected forms, and derivations. Syntactic patterns can be coded at the most elementary level in terms of item-based patterns, which are then grouped on the next level of abstraction into constructions, and eventually general syntactic patterns. Mental models are based on an interlocking system of role assignment, space-time configuration, causal relations, and perspective taking. This decomposition of the levels of language processing, as displayed in Table 1, derives from structural analysis (Hockett 1960).

Table 1. Levels of linguistic processing

Map	Area	Processes	Theory
1. Input Phonology	auditory cortex	extracting units	statistical learning
2. Output Phonology	IFG, motor cortex	targets, timing	avalanches, gating
3. Semantics	Distributed	imagery	embodied cognition
4. Lexicon	Wernicke's area	gangs, fields	DevLex, resonance
5. Syntax	IFG	slots, sequences	item-based patterns
6. Mental Models	dorsal cortex	deixis, roles	perspective theory
7. Interaction	social network	sequencing, affiliation	CA, sociolinguistics

The levels distinguished by structural analysis are richly interconnected. This means that, although they are partially decomposable, they are not modular in the sense of Fodor (1983) but rather interactive in the sense of McClelland (1987). In order to achieve gating and activation, processing levels must be interconnected in a way that permits smooth coordination. The UCM assumes that these interconnections rely on methods for topological organization that are used throughout the cortex (Hauk, Johnsrude & Pulvermuller 2004; Wessinger, Buonocore, Kussmaul & Mangun 1997).

Structural analysis has many important consequences for our understanding of relations between first and second language learning. Age-related first language entrenchment operates in very different ways in different cortical areas (Werker

and Hensch 2014; MacWhinney, in press). In second language production, contrasts and timing relations between the levels of conceptualization, formulation, and articulation (Levelt 1989) produce marked effects on language performance (Skehan 2009), although similar effects can be found also in first language acquisition (Snow 1999).

2.3 Timeframes

To fully understand the mechanics of learning and processing, we must also examine how structural levels operate across contrasting timeframes (MacWhinney 2005, 2013). Broadly speaking, we can distinguish four major timeframes:

1. *Processing*
   The timeframe of processing occurs at the moment of speaking. Here, psycholinguists have focused on the neural basis for online processing of words and sentences during production and comprehension, whereas conversation analysts have focused on the social basis for the ways in which we take turns and share ideas.
2. *Consolidation*
   Online processing leads to the storage of experiential traces in memory. Some traces last only for seconds, whereas others persist across decades. Memory processes can also support the emergence of higher levels of structure through generalization that vary through the course of a human lifespan.
3. *Social Diffusion*
   Linguistic forms diffuse through processes of social memesis (Mesoudi, Whiten & Laland 2006) across interactional networks. Sociolinguists have shown that the changes triggered by these processes can extend across days or centuries.
4. *Genetic Diffusion*
   Within timeframes ranging from decades to millennia, we can trace the diffusion and consolidation of genetic support for producing spoken and written language (Arbib 2014).

3. Risk factors and support factors

The UCM extends the classic Competition Model by providing characterizations of additional neurocognitive, developmental, and social forces that control competition. These forces operate on very different time scales, varying from seconds to years (MacWhinney 2014). However, all of these forces have their effect at the moment of speaking by imparting strength to particular cues and by affecting the

timing of the interaction between cues. Some of these forces operate to restrict the smooth acquisition of second languages. We can refer to these as "risk factors". Other forces serve to promote both first and second language learning. We can refer to these as "support factors".

Table 2 presents these factors in terms of these two dimensions. This analysis of the task of second language learning into risk and support factors is provided as an emergentist replacement for the earlier concept of Critical Periods. In the next sections we discuss each of the four risk factors and ways in which their negative effects can be mitigated through reliance on support factors.

Table 2. Risk factors and support factors for second language learning

Risk factors	Support factors
Entrenchment	Resonance
Transfer	Decoupling
Overanalysis	Chunking
Isolation	Participation

The increased availability of support factors in adulthood can be linked to the overall growth of executive function discussed earlier, because proper application of each of these support processes requires some executive control. Krashen (1994) has claimed that the growth of executive control over language can lead to a blockage of natural processes, leading to "learning" rather than "acquisition". The UCM takes a sharply contrasting position on this issue, holding that executive control can allow adults to make use of support processes that help them to overcome the limitations of the four risk factors. In this regard, it is interesting to note that habitual use of executive control processes in adulthood can function as a general method for developing protection against intellectual decline (Bialystok, Craik & Luk 2012; Stern 2009).

3.1 Entrenchment

Entrenchment is a basic neurodevelopmental process. At birth, the cerebral cortex of the human infant is designed to process general auditory patterns, but this processing is not yet language specific. Across the first years, neural territory becomes increasingly committed to the patterns of the first language. The structuring of cortical areas to achieve efficient processing has important consequences for age-related changes in language learning. For example, motor cortex has two parallel systems, one of which is hard-wired and entrenched and one that remains plastic throughout development (Yamamoto, Hoffman & Strick 2006), making motor

relearning possible. The UCM postulates that differences in the ways in which specific cortical areas undergo entrenchment will lead to variations in age-related effects for specific linguistic levels. In particular, the hard-wired nature of connections between motor cortex and motor pathways will make it difficult to undo or retune aspects of articulatory planning (Major 1987). Auditory cortex also shows signs of early commitment and entrenchment (Kuhl, Conboy, Padden, Nelson & Pruitt 2005), along with retention of a capacity for reorganization (Zhou, Panizutti, de Villers-Sidani, Madeira & Merzenich 2011). In contrast, the greater plasticity and interconnectedness of temporal cortex with other areas (Kemmerer 2015) make it possible for adults to acquire L2 vocabulary at a faster rate than children (Nation 2001; Snow & Hoefnagel-Hohle 1978). Ongoing studies of the relative plasticity of different cortical areas will help connect predictions from neuroscience to observed patterns of L2 learning.

The processes of commitment and entrenchment can be modeled using self-organizing maps (Kohonen 2001), a computational formalism that reflects many of the basic facts of neural structure. Simulations of lexical learning from real input to children have shown how the organization of lexical fields into parts of speech becomes increasingly inflexible across learning. The detailed operation of these processes has been modeled for lexical and phonological structure using DevLex (Li et al. 2007) and for auditory structure using DIVA (Guenther & Gjaja 1996). The UCM assumes that cortical maps exist for each of the structural levels in Table 1, including syntax (Pulvermüller 2003) and mental models (MacWhinney 2008).

3.2 Resonance

The risk factor of entrenchment can be counteracted by the support factor of resonance. Resonance provides new encoding dimensions to reconfigure old neuronal territory, permitting clearer encoding of L2 patterns. Because this encoding operates against the underlying forces of entrenchment, special configurations are needed to support resonance. Resonance can be illustrated most easily in the domain of lexical learning. Since the days of Ebbinghaus (1885) we have understood that the learning of the associations between words requires repeated practice. However, a single repetition of a new vocabulary pair such as *mesa – table* is not enough to guarantee robust learning. Instead, it is important that initial exposure be followed by further repetitions timed to provide correct retrieval before forgetting prevents efficient resonance from occurring (Pavlik & Anderson 2005). Because robustness accumulates with practice, later retrieval trials can be spaced farther and farther apart. This is the principle of "graduated internal recall" that was formulated for second language learning by Pimsleur (1967).

The success of graduated interval recall can be attributed in part to its use of resonant neural connections between cortical areas. While two cortical areas are coactive, the hippocampus can store their relation long enough to create an initial memory consolidation. Repeated access to this trace (Wittenberg, Sullivan & Tsien 2002) can further consolidate the memory. Once initial consolidation has been achieved, maintenance only requires occasional reactivation of the relevant retrieval pathway. This type of resonance can be used to consolidate new forms on the phonological, lexical (Gupta & MacWhinney 1997), and construction levels.

The success of graduated interval recall also depends on correctly diagnosing the point at which a new memory trace is still available, albeit slightly weakened. At this point, when a learner attempts to remember a new word, sound, or phrase, some additional work will be needed to generate a retrieval cue. This retrieval cue then establishes a resonance with the form being retrieved. This resonant cue may involve lexical analysis, onomatopoeia, imagery, physical responses, or some other relational pattern. Because there is no fixed set of resonant connections (Ellis & Beaton 1995), we cannot use group data to demonstrate the use of specific connections in lexical learning. However, we do know that felicitous mnemonics provided by the experimenter (Atkinson 1975) can greatly facilitate learning.

Orthography provides a major support for resonance in L2 learning. When a learner of German encounters the word *Wasser*, it is possible to map the sounds of the word directly to its orthography, as well as to the visual-tactile image of water. Because German has highly regular mappings from orthography to pronunciation, calling up the image of the spelling of *Wasser* is an extremely good way of activating its sound. When the L2 learner is illiterate, or when the L2 orthography is unlike the L1 orthography, this backup orthographic system is not available to support resonance. L2 learning of Chinese by speakers of languages with Roman scripts illustrates this problem. In some signs and books in Mainland China, Chinese characters are accompanied by Romanized Pinyin spellings. This provides the L2 learner with a method for establishing resonant connections between new words, their pronunciation, and their representations in Chinese orthography. However, in Taiwan and Hong Kong, characters are seldom written out in Pinyin in either books or public notices. As a result, learners cannot develop resonant connections from these materials. In order to make use of resonant connections from orthography, learners must focus on the learning of Chinese script. This learning itself requires constructing other resonant associations, because the Chinese writing system is based in large part on radical elements that have multiple potential resonant associations with the sounds and meanings of words.

3.3 Transfer

In L2 learning, new forms must be entered into maps that are already heavily committed to L1 patterns. One way of solving this problem is to align L2 forms with analogous L1 forms. When the forms align well, mapping an L1 form to L2 will result in *positive transfer*. But when there are mismatches, then the alignment produces *negative transfer*. However, both forms of transfer lead initially to a *parasitic* relation of L2 forms and concepts on L1. In the Revised Hierarchical Model, Kroll has emphasized the extent to which beginning second language learners depend on preexisting L1 pathways for mediating the activation of L2 lexical items (J. Kroll & Sholl 1992). For example, when hearing the word *perro* "dog" in Spanish, the learner may first translate the word into English and then use the English word to access the meaning. At this point, the use of the Spanish word is *parasitic* on English-based knowledge. Later on, the word *perro* comes to activate the correct meaning directly. In this sense, parasitism is a direct and nearly inevitable initial consequence of transfer.

The UCM holds that L2 learners will attempt transfer whenever they can perceive a match between an item in L1 and a corresponding item in L2. Within industrialized cultures, it is often easy to transfer the basic pragmatic functions that help structure conversations and the construction of mental models. The transfer of lexical meaning from L1 to L2 is also largely positive, although there will be some mismatches in meaning (Dong, Gui & MacWhinney 2005) and translation ambiguities (Prior, MacWhinney & Kroll 2007). We also expect transfer from L1 to L2 for auditory and articulatory maps. It is reasonable enough to map a Chinese /p/ to an English /p/, even though the Chinese sound has a different time of voicing onset and no aspiration. The result of this type of imperfect transfer is what leads to the establishment of a foreign accent in L2 learners. Transfer is also easy enough for the semantics of lexical items (Judith Kroll & Tokowicz 2005). In this area, transfer is often largely positive, particularly between languages with similar linguistic and cultural patterns. In the initial stages of L2 word learning, this type of transfer requires very little reorganization, because L2 forms are initially parasitic upon L1 forms.

However, transfer is difficult or impossible for item-based syntactic patterns (MacWhinney 2005), because these patterns cannot be readily matched across languages. For the same reason, transfer is unlikely for the formal aspects of conjugational or declensional patterns and classes. The fact that transfer is difficult for these systems does not mean that they are easy for L2 learners, but rather that they must be learned from the bottom up without any support from the L1.

When learners have several possible L1 forms that can transfer to L2, they tend to prefer to transfer the least marked forms (Eckman 1977; Major & Faudree

1996). For example, as Pienemann, Di Biase, Kawaguchi, and Håkansson (2005) have noted, Swedish learners of German prefer to transfer to German the unmarked Swedish word order that places the subject before the tense marker in the German equivalent of sentences such as *Peter likes milk today*. Although Swedish has a pattern that allows the order *Today likes Peter milk*, learners tend not to transfer this pattern initially, because it is the more marked alternative.

3.4 Decoupling

To counter the risk factor of transfer, the learner needs to engage the support factor of decoupling. This process works to access words, meanings, syntactic structures, and phonological forms directly without mediation through L1. To achieve decoupling, the learner needs to think and operate in L2 without switching back to L1 or relying on L1 structures. Working in L2 without recourse to L1 can rely in part on inner speech (Vygotsky 1934) and in part on assuming an L2 identity(Pavlenko & Lantolf 2000). When we activate inner speech, we are using language to build up mental models to control our thinking and plans. Vygotsky (1934) observed that young children would often give themselves instructions overtly. For example, a two-year-old might say, "pick it up" while picking up a block. At this age, the verbalization guides the action (Asher 1969). Later, as Vygotsky argues, these overt instructions become inner speech and continue to guide our cognition. L2 learners go through a process much like that of the child (Berk 1994; Nelson 1998). At first, they use the language only with others. Then, they begin to talk to themselves in the new language and start to "think in the second language." At this point, the second language begins to assume the same independent status that the first language attains for the child.

Decoupling also helps us understand the growth of the ability to engage in code switching. If a language is being repeatedly accessed, it will be in a highly resonant state. Although another language will be passively accessible, it may take a second or two before the resonant activation of that language can be triggered by a task (Grosjean 1997). Thus, a speaker may not immediately recognize a sentence in a language that has not been spoken in the recent context. On the other hand, a simultaneous interpreter will maintain both languages in continual receptive activation, while trying to minimize resonant activations in the output system of the source language.

3.5 Overanalysis

The third risk factor facing the adult L2 learner is overanalysis. Because adults learn L2 words more quickly than children (Snow & Hoefnagel-Hohle 1978), they tend to process L2 input by pulling out recognizable lexical forms. This allows them to quickly grasp the general meaning of an utterance, but it also means that they do not pick up longer stretches or phrases as single items. Thus, in both perception and production, they tend to pass over or miss the function words and grammatical markers which play such an important role in the L2 system. For example, learners of German often learn the word *Mann* "man" in isolation. If, instead, they would learn phrases such as *der alte Mann, meines Mannes, den jungen Männern*, and *ein guter Mann*, they would have a good basis for acquiring the declensional paradigm for both the noun and its modifiers. If learners were to store larger chunks of this type, then the rules of grammar could emerge from analogic processing of the chunks stored in feature maps (Bybee & Hopper 2001; Ellis 2002; MacWhinney 1982; Tomasello 2003). However, if learners analyze a phrase like *der alte Mann* into the literal string "the + old + man" and throw away all of the details of the inflections on "der" and "alte," then they will lose an opportunity to induce the grammar from implicit generalization across stored chunks.

3.6 Chunking

The antidote to overanalysis is chunking. In perception, chunking involves segmenting the input into either already learned chunks or new stretches that are acquired as new chunks (McCauley, Monaghan & Christiansen 2015). The term "chunking" is also often used for a related process that operates primarily in production to achieve fluency. This is the process of *proceduralization* (Anderson 1993) that transfers material in declarative memory into a smoothly operating procedure requiring minimal attentional control. Because proceduralization results in the formation of production units, it is closely related to *chunking* (Newell 1990). Cognitive models differ in how they formalize the relation between proceduralization and chunking. The UCM use the term *proceduralization* to refer to the unitization of sequences that unfold in time, whereas *chunking* refers to the unitization of simultaneous perceptions or single words. Chunks function as single, unanalyzed lexical wholes or formulas (Sidtis 2014), whereas procedures are more relevant to syntax and may have room for flexible variation. For example, in Spanish, L2 learners can learn *muy buenos días* "very good morning" as a chunk. This chunk is based on a series of connections between preexisting lexical items, stored within the lexical map in the posterior cortical areas in the temporal lobe. However, this pattern could also

be learned as a flexible procedure triggered by the word *muy* "very" that would allow other completions such as *muy buenas tardes* "good afternoon" or *muy buenas noticias* "very good news".

Chunking focuses on storage in posterior lexical areas, whereas proceduralization relies on storage in frontal areas for sequence control (Broca's) that then point to lexical items in posterior areas. Proceduralization is initially less robust than chunking, but it is capable of greater extensibility and flexibility (Gobet 2005) across constructions beyond the level of the item-based construction. For example, a Spanish phrase such as *quisiera comprar…* (I would like to buy…) can be used with any manner of noun to talk about things you would like to buy. In each of these cases, having produced one initial combination, such as *quisiera comprar una cerveza* (I would like to buy a beer) may be halting at first. However, soon the result of the creation process itself can be stored as a chunk. In this case, it is not the actual phrase that is chunked, but rather the process of activating the predicate combination (*quisiera comprar*) and then going ahead and filling the argument. In other words, we develop fluency by repeated practice in making combinations.

Once learners have developed fluency in the combination of well-learned words, they can still experience disfluency when trying to integrate newly learned words into established constructions. For example, even if we have learned to use the frame *quisiera comprar* fluently with words such as *una cerveza* (a beer) or *un reloj* (a clock), we may still experience difficulties when we need to talk about buying "a round trip ticket to Salamanca" (*un billete de ida y vuelta para Salamanca*). In this selection, we might have particular problems when we hit the word *para* since the English concept of "for, to" can be expressed in Spanish using either *por* or *para* and our uncertainty regarding the choice between these two forms can slow us down and cause disfluency or error. In general, for both L1 and L2 learners, disfluencies arise from delays in lexical access, misordering of constituents, and selection of agreement markings. Fluency arises through the practicing of argument filling and improvements in the speed of lexical access and the selections between competitors.

Paradis (2004) argues that L2 learners cannot fully proceduralize a second language, and that L2 productions must remain forever slow and non-fluent. We can refer to this position as the *Proceduralization Deficit Hypothesis* (PDH). This hypothesis is a specific articulation of the general Critical Period Hypothesis (CPH). In this regard, we can point to work using artificial language systems (Friederici, Steinhauer & Pfeifer 2002; Müller, Hahne, Fujii & Friederici 2005) that shows how, if the rules of the target language are simple and consistent, L2 learners can develop proceduralization, as measured by an early left anterior negativity (ELAN) response, a couple of months of training. Thus, it appears that proceduralization can be successful in adult learners, as long as cues are consistent, simple, and reliable

(MacWhinney 1997; Tokowicz & MacWhinney 2005). This finding is in accord with the UCM analysis, rather than the PDH analysis, because it shows that the crucial factor here is not the age of the learner, but the shape of the input.

It is important not to confuse proceduralization with implicit learning. Although L1 learning relies primarily on implicit learning, L2 learning involves a complex interaction of both explicit and implicit learning. In formal contexts such as classrooms, a second language may be learned through explicit methods. However, this knowledge can then become proceduralized and automatized, producing good fluency. The effects of clear, explicit instruction are illustrated in a computerized tutorial system for teaching the gender of French nouns (Presson, MacWhinney & Tokowicz 2014). In this experiment, participants who knew no French were given simple cues to French gender. They were able to achieve 90% accurate gender assignment across 23 cue types, after only 90 minutes of computerized practice in the use of these cues. Moreover, this ability was retained across three months without any further training.

In a review of the role of explicit rule presentation, MacWhinney (1997) argued that L2 learners can benefit from explicit cue instruction, as long as the cues are presented simply and clearly. Once a simple pattern has been established in explicit declarative form, repeated exposures to a cue can use the scaffolding of the explicit pattern to establish proceduralization. As in the case of lexical learning, the method of graduated interval recall can further support proceduralization. In addition, error correction can help to tune cue weights (McDonald & Heilenman 1991). Of course, proceduralization can be achieved without scaffolding from explicit instruction. However, if explicit scaffolding is available, learning will be faster.

3.7 Isolation

The fourth risk factor for older L2 learners is social isolation. As we get older, full integration into a second language community can become increasingly difficult. There are at least three reasons for this. First, as we age, it can become increasingly difficult to set aside L1 allegiances and responsibilities. Second, L2 communities tend to be more immediately supportive of younger L2 learners. As children get older, peer groups become increasingly critical of participants who fail to communicate in accepted ways. Third, as we age, we may develop images regarding our social status that make it difficult to accept corrective feedback, teasing, or verbal challenges, even if these are excellent sources of language input. The cumulative effect of these social factors is that positive support for language learning can decrease markedly across the lifespan. Unless older learners focus directly on making friends in the new community and developing a full L2 persona (Pavlenko & Lantolf 2000),

they can become isolated and cut off. The cognitive consequences of these social patterns is the loss of both comprehensible input (Krashen 1994) and opportunities to engage in fluent output (Swain 2005).

3.8 Participation

The antidote to isolation is participation. Older learners can increase their participation in the L2 community in a variety of ways. They can join religious groups, athletic teams, or work groups. Often these groups are highly motivated to improve the language abilities of new members, so that they can function smoothly within the group. Older learners can also engage in formal study and expose themselves to L2 input through books, films, and music. When these methods for increasing participation operate in concert with the processes of chunking, resonance, and decoupling, L2 learning will lead to increasingly high levels of fluency and correctness. Formal instruction can also incorporate insights from activity theory (Engeström 1999; Ratner 2002) to guide a contextualized curriculum. Many syllabi already make use of a simple form of activity theory when they compose units based on specific activities such as ordering food at a restaurant, asking for directions, dealing with car problems, or transferring money across bank accounts. Multimodal video materials linked to transcripts can be used to further support this type of activity-based learning of vocabulary, pragmatics, and syntax.

3.9 Applications

The formulation of risk factors and support factors provided by the Unified Competition Model has important implications for the teaching of second languages. For learners in the preschool and early school years, the risk factors of entrenchment, overanalysis, and isolation are not yet serious concerns. Transfer will lead to some initial problems, but they can be overcome. These learners can acquire additional languages using more or less the same methods they used to pick up their first language. At this age, instruction should focus on providing rich input and opportunities to talk. Just like adults, children need to focus their attention explicitly on words, sounds, and constructions. However, they can learn without corrective feedback, because they find it so easy to pick up new phrases without having to combat heavily entrenched forms. For children learning a second language, the principle danger is that, once instruction or exposure to a language ceases, they will soon lose their ability to use that language (Burling 1959). In other words, children are particularly susceptible to L1 attrition (Schmid 2011). For immigrant children, the major challenge during this period is to provide social situations that

allow them to integrate fully into peer group contexts (McLaughlin 1985). During the middle school years, second language instruction should become increasingly explicit. For 10-year-olds, instruction can still rely principally on songs, phrases, and games. However, adolescents will begin to shift into adult mode in terms of relying on resonance, decoupling, chunking, and participation.

For adolescent and adult learners, instruction should include both contextualized and decontextualized components. Decontextualized components should focus on the resonant practice of basic skills in auditory phonology, articulatory phonology, lexicon, and syntactic constructions. This type of basic skills practice can be controlled through computerized presentation with the results tailored to the individual student level (Pavlik et al. 2007) and relying on the method of graduated interval recall to maximize efficiency. We have implemented systems of this type <http://talkbank.org/SLA> for learning Chinese sound patterns through Pinyin dictation, Chinese vocabulary, French dictation, and French gender (Presson et al. 2014). These online systems automatically provide the instructor with students' scores to allow them to monitor students' progress through each phase of each module. Basic skills training should first focus on chunking (Yoshimura & MacWhinney 2007) and resonance.

In parallel with decontextualized training, learners can rely on contextualized materials for promoting internalization and participation. Computerized presentation of realistic video interactions linked to transcripts can be particularly effective, as in the DOVE transcript browser illustrated at <http://talkbank.org/DOVE>. These various methods, both contextualized and decontextualized, can be integrated into a single learning platform deployed on web-connected laptops and tablets, in accord with the Language Partner system (Presson, Davy & MacWhinney 2013). Mobile devices can be used to record real-life interactions (Clark, Wagner, Lindemalm & Bendt 2011) for later analysis in the classroom. For example, a learner of Icelandic recorded her interactions in a bakery in Rejkjavik. These data were transcribed and the transcripts were linked to audio records. The resulting corpus, called IceBase, was used by Guðrún Theodórsdóttir as the basis for her dissertation in the Conversation Analysis framework and the relevant data are available to researchers from <http://talkbank.org>. In the classroom, these materials could help students understand conversational practices, pragmatic norms, linguistic forms, and methods for negotiating meaning. Instructors can also configure learning tours of the type illustrated at <http://talkbank.org/SLA/tours> in which students are guided through the city to promote interactions with people in stores, restaurants, buses, and museums to learn more about the city and the language.

4. Summary

The classic version of the Competition Model was based on three decades of empirical studies of first and second language learners. To account for the dynamics of second language learning, the details of age-related changes in learning success, the role of social factors, and our growing understanding of the brain, it was necessary to extend the model to deal with the processes of entrenchment, transfer, overanalysis, and isolation that constitute risk factors for second language learners. To counter these risk factors, second language learners can maximize their reliance on the support factors of resonance, decoupling, chunking, and participation that are also available to first language learners. Together, these processes constitute components of a unified model of both first and second language acquisition.

References

Anderson, J. 1993. *Rules of the Mind*. Hillsdale NJ: Lawrence Erlbaum Associates.

Arbib, M. 2014. Language evolution: An emergentist perspective. In *Handbook of Language Emergence*, B. MacWhinney & W. O'Grady (eds). New York NY: Wiley.

Asato, M. R., Terwilliger, R., Woo, J. & Luna, B. 2010. White matter development in adolescence: A DTI study. *Cerebral Cortex* 20: 2122–2131. doi:10.1093/cercor/bhp282

Asher, J. 1969. The total physical response approach to second language learning. *The Modern Language Journal* 53: 3–17.

Atkinson, R. 1975. Mnemotechnics in second-language learning. *American Psychologist* 30: 821–828. doi:10.1037/h0077029

Bates, E. & MacWhinney, B. 1982. Functionalist approaches to grammar. In *Language Acquisition: The State of the Art*, E. Wanner & L. Gleitman (eds), 173–218. Cambridge: CUP.

Bates, E., McNew, S., MacWhinney, B., Devescovi, A. & Smith, S. 1982. Functional constraints on sentence processing: A cross-linguistic study. *Cognition* 11: 245–299. doi:10.1016/0010-0277(82)90017-8

Berk, L. E. 1994. Why children talk to themselves. *Scientific American* 273: 78–83. doi:10.1038/scientificamerican1194-78

Bialystok, E., Craik, F. & Luk, G. 2012. Bilingualism: Consequences for mind and brain. *Trends in Cognitive Sciences* 16: 240–250. doi:10.1016/j.tics.2012.03.001

Birdsong, D. 2005. Interpreting age effects in second language acquisition. In *Handbook of Bilingualism: Psycholinguistic Approaches*, J. F. Kroll & A.M.B. de Groot (eds), 109–128. Oxford: OUP.

Bley-Vroman, R. 2009. The evolving context of the fundamental difference hypothesis. *Studies in Second Language Acquisition* 31: 175–198. doi:10.1017/S0272263109090275

Bongaerts, T. 1999. Ultimate attainment in L2 pronunciation: The case of very advanced late L2 learners. In *Second Language Acquisition and the Critical Period Hypothesis*, D. Birdsong (ed.), 133–159. Mahwah NJ: Lawrence Erlbaum Associates.

Burling, R. 1959. Language development of a Garo and English speaking child. *Word* 15: 45–68. doi:10.1080/00437956.1959.11659683

Bybee, J. & Hopper, P. 2001. *Frequency and the Emergence of Linguistic Structure* [Typological Studies in Language 45]. Amsterdam: John Benjamins. doi: 10.1075/tsl.45

Casey, B. J., Giedd, J. N. & Thomas, K. M. 2000. Structural and functional brain development and its relation to cognitive development. *Biological Psychology* 54: 241–257. doi: 10.1016/S0301-0511(00)00058-2

Clark, B., Wagner, J., Lindemalm, K. & Bendt, O. 2011. *Språkskap: Supporting second language learning "in the wild"*. Paper presented at the INCLUDE, London.

DeKeyser, R. 2000. The robustness of critical period effects in second language acquisition studies. *Studies in Second Language Acquisition* 22: 499–533.

Dong, Y. -P., Gui, S. -C. & MacWhinney, B. 2005. Shared and separate meanings in the bilingual mental lexicon. *Bilingualism: Language and Cognition* 8: 221–238. doi: 10.1017/S1366728905002270

Doria, V., Beckman, C. F., Arichi, T. & Merchant, N. 2010. Emergence of resting state networks in the preterm human brain. *Proceedings of the National Academy of Sciences of the United States of America* 107: 20015–20020. doi: 10.1073/pnas.1007921107

Ebbinghaus, H. 1885. *Über das Gedächtnis*. Leipzig: Duncker.

Eckman, F. R. 1977. Markedness and the contrastive analysis hypothesis. *Language Learning* 27: 315–330. doi: 10.1111/j.1467-1770.1977.tb00124.x

Ellis, N. 2002. Frequency effects in language processing. *Studies in Second Language Acquisition* 24: 143–188.

Ellis, N. & Beaton, A. 1995. Psycholinguistic determinants of foreign language vocabulary learning. In *Lexical Issues in Language Learning*, B. Harley (ed.), 107–165. Amsterdam: John Benjamins.

Engeström, Y. 1999. Activity theory and individual social transformation. In *Perspectives on Activity Theory*, Y. Engeström, R. -L. Punamäki & R. Miettinen (eds), 1–15. Cambridge: CUP. doi: 10.1017/CBO9780511812774.002

Flege, J. E., Yeni-Komshian, G. H. & Liu, S. 1999. Age constraints on second-language acquisition. *Journal of Memory and Language* 41: 78–104. doi: 10.1006/jmla.1999.2638

Fodor, J. 1983. *The Modularity of Mind: An Essay on Faculty Psychology*. Cambridge MA: The MIT Press.

Friederici, A., Steinhauer, K. & Pfeifer, E. 2002. Brain signatures of artificial language processing: Evidence challenging the critical period hypothesis. *Proceedings of the National Academy of Sciences* 99: 529–534. doi: 10.1073/pnas.012611199

Gobet, F. 2005. Chunking models of expertise: Implications for education. *Applied Cognitive Psychology* 19: 183–204. doi: 10.1002/acp.1110

Grosjean, F. 1997. Processing mixed languages: Issues, findings and models. In *Tutorials in Bilingualism: Psycholinguistic Perspectives*, A.M.B. de Groot & J. F. Kroll (eds), 225–254. Mahwah NJ: Lawrence Erlbaum Associates.

Guenther, F. & Gjaja, M. 1996. The perceptual magnet effect as an emergent property of neural map formation. *Journal of the Acoustical Society of America* 100: 1111–1121. doi: 10.1121/1.416296

Gupta, P. & MacWhinney, B. 1997. Vocabulary acquisition and verbal short-term memory: Computational and neural bases. *Brain and Language* 59: 267–333. doi: 10.1006/brln.1997.1819

Hakuta, K., Bialystok, E. & Wiley, E. 2003. Critical evidence: A test of the critical period hypothesis for second language acquisition. *Psychological Science* 14: 31–38. doi: 10.1111/1467-9280.01415

Hauk, O., Johnsrude, I. & Pulvermuller, F. 2004. Somatotopic representation of action words in human motor and premotor cortex. *Neuron* 41: 301–307. doi: 10.1016/S0896-6273(03)00838-9

Hockett, C. F. 1960. The origin of speech. *Scientific American*, September, 6–12.

Johnson, J. S. & Newport, E. L. 1989. Critical period effects in second language learning: The influence of maturational state on the acquisition of English as a second language. *Cognitive Psychology* 21: 60–99. doi: 10.1016/0010-0285(89)90003-0

Kemmerer, D. 2015. *The Cognitive Neuroscience of Language*. New York, NY: Psychology Press.

Kempe, V. & MacWhinney, B. 1999. Processing of morphological and semantic cues in Russian and German. *Language and Cognitive Processes* 14: 129–171. doi: 10.1080/016909699386329

Kohonen, T. 2001. *Self-organizing Maps*, 3rd edn. Berlin: Springer. doi: 10.1007/978-3-642-56927-2

Krashen, S. 1994. The Input Hypothesis and its rivals. In *Implicit and Explicit Learning of Languages*, N. C. Ellis (ed.), 45–78. San Diego CA: Academic Press.

Kroll, J. & Sholl, A. 1992. Lexical and conceptual memory in fluent and nonfluent bilinguals. In *Cognitive Processing in Bilinguals*, R. Harris (ed.), 191–206. Amsterdam: North-Holland. doi: 10.1016/S0166-4115(08)61495-8

Kroll, J. & Tokowicz, N. 2005. Models of bilingual representation and processing. In *Handbook of Bilingualism: Psycholinguistic Approaches*, J. F. Kroll & A.M.B. de Groot (eds), 531–554. Oxford: OUP.

Kuhl, P. 2010. Brain mechanisms in early language acquisition. *Neuron* 67: 713–727. doi: 10.1016/j.neuron.2010.08.038

Kuhl, P., Conboy, B., Padden, D., Nelson, T. & Pruitt, J. 2005. Early speech perception and later language development: Implications for the "Critical Period". *Language Learning and Development* 1: 237–264. doi: 10.1080/15475441.2005.9671948

Lenneberg, E. 1967. *Biological Foundations of Language*. New York NY: Wiley.

Levelt, W. J. M. 1989. *Speaking: From Intention to Articulation*. Cambridge MA: The MIT Press.

Li, P., Zhao, X. & MacWhinney, B. 2007. Dynamic self-organization and early lexical development in children. *Cognitive Science* 31: 581–612. doi: 10.1080/15326900701399905

MacDonald, M., Pearlmutter, N. J. & Seidenberg, M. S. 1994. Lexical nature of syntactic ambiguity resolution. *Psychological Review* 101(4): 676–703. doi: 10.1037/0033-295X.101.4.676

MacWhinney, B. 1982. Basic syntactic processes. In *Language Acquisition, Vol. 1: Syntax and Semantics*, S. Kuczaj (ed.), 73–136. Hillsdale NJ: Lawrence Erlbaum Associates.

MacWhinney, B. 1987. The Competition Model. In *Mechanisms of Language Acquisition*, B. MacWhinney (ed.), 249–308. Hillsdale NJ: Lawrence Erlbaum Associates.

MacWhinney, B. 1997. Implicit and explicit processes. *Studies in Second Language Acquisition* 19: 277–281. doi: 10.1017/S0272263197002076

MacWhinney, B. 2005. Item-based constructions and the logical problem. *ACL 2005*: 46–54.

MacWhinney, B. 2008. How mental models encode embodied linguistic perspectives. In *Embodiment, Ego-Space, and Action*, R. Klatzky, B. MacWhinney & M. Behrmann (eds), 369–410. Mahwah NJ: Lawrence Erlbaum Associates.

MacWhinney, B. 2012. The logic of the Unified Model. In *The Routledge Handbook of Second Language Acquisition*, S. Gass & A. Mackey (eds), 211–227. New York NY: Routledge.

MacWhinney, B. 2014. Conclusions: Competition across time. In *Competing Motivations in Grammar and Usage*, B. MacWhinney, A. Malchukov & E. Moravcsik (eds), 364–386. Oxford: OUP. doi: 10.1093/acprof:oso/9780198709848.003.0022

MacWhinney, B. & O'Grady, W. (eds). 2015. *The Handbook of Language Emergence*. New York NY: Wiley. doi: 10.1002/9781118346136

MacWhinney, B. In press. Entrenchment in second language learning. In *Entrenchment*, H. -J. Schmid (ed.). New York NY: American Psychological Association.

Major, R. 1987. The natural phonology of second language acquisition. In *Sound Patterns in Second Language Acquisition*, A. James & J. Leather (eds), 207–224. Dordrecht: Foris.

Major, R. & Faudree, M. 1996. Markedness universals and the acquisition of voicing contrasts by Korean speakers of English. *Studies in Second Language Acquisition* 18: 69–90. doi: 10.1017/S0272263100014686

Matessa, M. & Anderson, J. 2000. Modeling focused learning in role assignment. *Language and Cognitive Processes* 15: 263–292. doi: 10.1080/016909600386057

McCauley, S., Monaghan, P. & Christiansen, M. 2015. Usage-based language learning. In *The Handbook of Language Emergence*, B. MacWhinney & W. O'Grady (eds), 415–436. New York NY: Wiley.

McClelland, J. 1987. The case for interactionism in language processing. In *Attention and Performance, XII: The Psychology of Reading*, M. Coltheart (ed.), 3–36. Hillsdale NJ: Lawrence Erlbaum Associates.

McDonald, J. 1986. The development of sentence comprehension strategies in English and Dutch. *Journal of Experimental Child Psychology* 41: 317–335. doi: 10.1016/0022-0965(86)90043-3

McDonald, J. & Heilenman, K. 1991. Determinants of cue strength in adult first and second language speakers of French. *Applied Psycholinguistics* 12: 313–348. doi: 10.1017/S0142716400009255

McLaughlin, B. 1985. *Second-Language Acquisition in Childhood*. Hillsdale NJ: Lawrence Erlbaum Associates.

Mills, D., Coffey-Corina, S. & Neville, H. 1997. Language comprehension and cerebral specialization from 13 to 20 months. *Developmental Neuropsycholog*, 13: 397–445. doi: 10.1080/87565649709540685

Molfese, D. L., Freeman, R. D. & Palermo, D. S. 1975. The ontogeny of brain lateralization for speech and nonspeech stimuli. *Brain and Language* 2: 356–368. doi: 10.1016/S0093-934X(75)80076-9

Müller, J., Hahne, A., Fujii, Y. & Friederici, A. 2005. Native and nonnative speakers' processing of a miniature version of Japanese as revealed by ERPs. *Journal of Cognitive Neuroscience* 17: 1229–1244. doi: 10.1162/0898929055002463

Munakata, Y., McClelland, J., Johnson, M. & Siegler, R. 1997. Rethinking infant knowledge: An adaptive process account of successes and failures in object permanence tasks. *Psychological Review* 104: 686–713. doi: 10.1037/0033-295X.104.4.686

Nation, P. 2001. *Learning Vocabulary in Another Language*. Cambridge: CUP. doi: 10.1017/CBO9781139524759

Nelson, K. 1998. *Language in Cognitive Development: The Emergence of the Mediated Mind*. Cambridge: CUP.

Newell, A. 1990. *A Unified Theory of Cognition*. Cambridge MA: Harvard University Press.

Paradis, M. 2004. *A Neurolinguistic Theory of Bilingualism* [Studies in Bilingualism 18]. Amsterdam: John Benjamins. doi: 10.1075/sibil.18

Pavlenko, A. & Lantolf, J. 2000. Second language learning as participation and the (re)construction of selves. In *Sociocultural Theory and Second Language Learning*, A. Pavlenko & J. Lantolf (eds), 155–178. Oxford: OUP.

Pavlik, P. & Anderson, J. 2005. Practice and forgetting effects on vocabulary memory: An activation-based model of the spacing effect. *Cognitive Science* 29: 559–586. doi: 10.1207/s15516709cog0000_14

Pavlik, P., Presson, N., Dozzi, G., Wu, S., MacWhinney, B. & Koedinger, K. R. 2007. The FaCT (Fact and Concept Training) system: A new tool linking cognitive science with educators. *Proceedings of the 29th Annual Conference of the Cognitive Science Society*, 1379–1384. Nashville TN: Cognitive Science Society.

Pienemann, M., Di Biase, B., Kawaguchi, S. & Håkansson, G. 2005. Processing constraints on L1 transfer. In *Handbook of Bilingualism: Psycholinguistic Approaches*, J. F. Kroll & A.M.B. de Groot (eds), 128–153. Oxford: OUP.

Pimsleur, P. 1967. A memory schedule. *Modern Language Journal* 51: 73–75. doi: 10.1111/j.1540-4781.1967.tb06700.x

Presson, N., Davy, C. & MacWhinney, B. 2013. Experimentalized CALL for adult second language learners. In *Innovative Research and Practices in Second Language Acquisition and Bilingualism* [Language Learning and Language Teaching 38], J. Schwieter (ed.), 139–164. Amsterdam: John Benjamins. doi: 10.1075/lllt.38.10pre

Presson, N., MacWhinney, B. & Tokowicz, N. 2014. Learning grammatical gender: The use of rules by novice learners. *Applied Psycholinguistics* 35: 709–737. doi: 10.1017/S0142716412000550

Prior, A., MacWhinney, B. & Kroll, J. 2007. Translation norms for English and Spanish: The role of lexical variables, word class, and L2 proficiency in negotiating translation ambiguity. *Behavior Research Methods* 37: 134–140.

Pulvermüller, F. 2003. *The Neuroscience of Language*. Cambridge: CUP. doi: 10.1017/CBO9780511615528

Ratner, C. 2002. *Cultural Psychology: Theory and Method*. New York NY: Plenum. doi: 10.1007/978-1-4615-0677-5

Schmid, M. 2011. *Language Attrition*. Cambridge: CUP. doi: 10.1017/CBO9780511852046

Sidtis, D. 2014. Formulaic language: Acquisition, use, and neurological foundations. In *Handbook of Language Emergence*, B. MacWhinney & W. O'Grady (eds), 578–600. New York NY: Wiley.

Simon, H. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society* 106: 467–482.

Skehan, P. 2009. Modelling second language performance: Integrating complexity, accuracy, fluency, and lexis. *Applied Linguistics* 30: 510–532. doi: 10.1093/applin/amp047

Snow, C. E. 1999. Social perspectives on the emergence of language. In *The Emergence of Language*, B. MacWhinney (ed.), 257–276. Mahwah NJ: Lawrence Erlbaum Associates.

Snow, C. E. & Hoefnagel-Hohle, M. 1978. The critical period for language acquisition: Evidence from second language learning. *Child Development* 49: 1114–1128. doi: 10.2307/1128751

Stern, Y. 2009. Cognitive reserve. *Neuropsychologia* 47(10): 2015–2028. doi: 10.1016/j.neuropsychologia.2009.03.004

Swain, M. 2005. The output hypothesis: Theory and research. In *Handbook of Research in Second Language Teaching and Learning*, E. Hinkel (ed.), 471–484. Mahwah NJ: Lawrence Erlbaum Associates.

Taraban, R. & Palacios, J. M. 1993. Exemplar models and weighted cue models in category learning. In *Categorization by Humans and Machines*, G. Nakamura, R. Taraban & D. Medin (eds), 91–127. San Diego CA: Acdemic Press.

Tokowicz, N. & MacWhinney, B. 2005. Implicit and explicit measures of sensitivity to violations in second language grammar: An event-related potential investigation. *Studies in Second Language Acquisition* 27: 173–204. doi: 10.1017/S0272263105050102

Tomasello, M. 2003. *Constructing a First Language: A Usage-Based Theory of Language Acquisition*. Cambridge MA: Harvard University Press.

Vygotsky, L. S. 1934. *Thought and Language*. Cambridge MA: The MIT Press.

Waddington, C. H. 1957. *The Strategy of the Genes*. New York NY: MacMillan.

Werker, J. & Hensch, T. 2014. Critical periods in speech perception: New directions. *Annual Review of Psychology* 66: 173–196. doi: 10.1146/annurev-psych-010814-015104

Werker, J. & Tees, R. 2005. Speech perception as a window for understanding plasticity and commitment in language systems of the brain. *Developmental Psychobiology* 46: 233–251. doi:10.1002/dev.20060

Wessinger, C. M., Buonocore, M. H., Kussmaul, C. L. & Mangun, G. R. 1997. Tonotopy in human auditory cortex examined with functional magnetic resonance imaging. *Human Brain Mapping* 5: 18–25. doi:10.1002/(SICI)1097-0193(1997)5:1<18::AID-HBM3>3.0.CO;2-Q

Wittenberg, G., Sullivan, M. & Tsien, J. 2002. Synaptic reentry reinforcement based network model for long-term memory consolidation. *Hippocampus* 12: 637–647. doi:10.1002/hipo.10102

Yamamoto, K., Hoffman, D. S. & Strick, P. 2006. Rapid and long lasting plasticity of input output mapping *Journal of Neurophysiology* 96: 2797–2798. doi:10.1152/jn.00209.2006

Yoshimura, Y. & MacWhinney, B. 2007. The effect of oral repetition in L2 speech fluency: System for an experimental tool and a language tutor. *SLATE Conference*, 25–28.

Zhou, X., Panizutti, R., de Villers-Sidani, É., Madeira, C. & Merzenich, M. 2011. Natural restoration of critical period plasticity in the juvenile and adult primary auditory cortex. *The Journal of Neuroscience* 31: 5625–5634. doi:10.1523/JNEUROSCI.6470-10.2011

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