The Competition Model: Past and Future

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1 Introduction

During the 1980s, Elizabeth Bates, Csaba Pléh, and Brian MacWhinney collaborated with colleagues working in 18 languages to elaborate a crosslinguistic model of language processing called the Competition Model (CM). Based on his earlier work on anaphor and text processing, Pléh made a series of fundamental contributions to the development of this model. By orthogonalizing the factors involved in Hungarian relative clause processing, he provided crucial tests between competing theoretical accounts (MacWhinney & Pléh, 1988). He tracked how young Hungarian children develop an understanding of the competing cues to agent assignment in simple transitive sentences (MacWhinney et al., 1985). He demonstrated how the processing of partially ungrammatical sentences involves the same mechanisms used in processing the corresponding grammatical sentences (Pléh, 1989), and he showed how the model could account for the ways in which Hungarian verbs agree with both the person and number of the subject and the definiteness of the object (MacWhinney & Pléh, 1997). All of these contributions were fundamental to the development of the Competition Model.

2 The Classic Competition Model

The Competition Model (CM) made its debut in Bates and MacWhinney (1982) as a mechanistic, functionalist account of language acquisition and processing. The claim in MacWhinney et al. (1984) was that "the forms of natural languages are

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created, governed, constrained, acquired, and used in the service of communicative functions." Furthermore, the model held that processing is based on an online competition between these communicative functions or motives.

Competition is fundamental to biological processes. Darwin (1859) showed how the evolution of a species emerges from the 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 processing, language development, diachronic language change, and language evolution are governed by these same three Darwinian principles.

2.1 Cues and Competition

There have been a large number of studies using the Competition Model framework to account for language acquisition, comprehension, production, and impairments. These experiments manipulate the ways in which languages users process *cues*. The model defines a cue as an information source present in the surface structure of utterances that allows the language user to link linguistic form with meaning or function. Cues vary in their *type* (morphological, syntactic, prosodic, semantic, and pragmatic), *availability* (how often they are present), and *reliability* (how often they lead to the correct interpretation). Each cue has a certain level of *cue validity*, the joint product of availability and reliability. Using conversational input data such as those available from the CHILDES https://childes.talkbank.org or other TalkBank https://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. Cues of the same basic type, such as case-marking, animacy, or word order may have markedly different levels of validity in different languages.

The extent to which cues dominate or control role assignments in experiments is the measure of their *cue strength*. The core claim of both the classic and unified versions of the Competition Model is that, for adults, cue strength is determined by cue validity. Cue strength is defined through experimental results; cue validity is defined through corpus counts.

The model holds that cues compete and coooperate during processing. Sometimes cues cooperate or converge by pointing to the same interpretation or production. Sometimes, cues compete by pointing to conflicting interpretations or productions. 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 the combination of 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 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.

2.2 Methods

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 method has been used in 62 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 four possible cue types: word order, case marking, agreement, and verb-based expectations. For simple transitive sentences with two nouns and a verb, the possible word orders are NNV, NVN, and VNN. The marking of the cases or thematic roles of nouns can rely on affixes (as with the accusative suffix in Hungarian or Turkish), postpositions (as with *ga* and *no* in Japanese), prepositions (as with the preposition *a* to mark the accusative in Spanish), or articles (as with the article *der* for masculine nominative in German). Agreement marking displays correspondences between the subject and the verb (as with the third person singular *-s* in English) or the object and the verb (as with the definite conjugation in Hungarian). Some of the features that can be marked through verb agreement include number (as in English), definiteness (as in Hungarian), gender (as in Arabic), honorific status (as in Japanese) and other grammatical features. Verb-based expectations can also control role assignment, as in the assignment of the experience and stimulus roles in psych verbs (McDonald & MacWhinney, 1995). Competition Model experiments put these various cues into systematic conflict using orthogonalized analysis of variance designs.

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 somewhat less reliable, cue of word order (McDonald, 1987).

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 et al., 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 readings of *communist* is initially resolved in favor of the adjectival readings, 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.

2.3 *Cue Cost*

When adult native speakers have sufficient time to make a careful decision, cue strength is correlated with cue reliability at levels above 0.90. 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 immediately integrating the effects of that core cue with other possible cues. This happens, for example, during online processing of sentences in Russian (Kempe & MacWhinney, 1998). 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 et al., 1982).

2.4 *Cue Detectability*

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.

2.5 *Findings*

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:

1. When given enough time to make a careful choice, adults assign the role of agent to the nominal with the highest cue strength.
2. 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.
3. 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.
4. When the strongest cue is either missing or neutralized by being coded on two separate nominal phrases, the next strongest cue will dominate.
5. The fastest decisions occur when all cues agree and there is no competition. The slowest decisions occur when strong cues compete.
6. Children begin learning to comprehend sentences by first focusing on the most available and detectable cue in their language.
7. As children get older, cue strengths converge on the adult pattern with the most reliable cue growing most in strength.
8. As children get older, their reaction times gradually get faster in accord with the adult pattern.
9. Compared to adults, children are relatively more influenced by cue availability, as opposed to cue reliability.
10. 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 measures the reliability of a cue when it conflicts directly with other cues.

11. 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 https://psyling.talkbank.org/guides/CM.html.

3 The Unified Competition Model

The classic Competition Model accounts well for many of the basic features of sentence processing and cue learning. It relies on a small set of assumptions regarding cues, validity, reliability, competition, transfer, and strength—each of which could be investigated directly. However, the model is limited in several important ways.

- Linguistic levels: The model focused primarily on the learning of morphosyntax without providing an account of development for the linguistic levels of audition, articulation, lexicon, or pragmatics.
- Brain structure: The classic model makes no contact with what we now know about the organization of language in the brain. As a result, it provides only incomplete understanding of patterns of language disorder and loss.
- Critical Period: The classic model fails to come to grips with the idea that there is a biologically-determined critical period for language acquisition.
- Motivation: The classic model provides no role for social and motivational factors governing language learning, preference, code-switching, and attrition.
- Mental models: The classic model fails to include a role for mental model construction during comprehension and formulation during production.
- Microgenesis: The classic model does not provide a microgenetic account for the course of item acquisition, fluency development, and cue strength learning.

Extending the classic model to deal with these challenges required borrowing heavily from insights in a variety of other theories, while maintaining the core concepts of competition, cues, cue strength, and cue validity developed in the classic Competition Model. The resultant broader theory is called the Unified Competition Model or UCM, because it seeks to unify a variety of independent theoretical frameworks into a single overall model. Moreover, the transition from the classic version of the model to the unified version worked to bring the model into fuller accord with the theory of emergentism, as developed in Systems Biology (West-Eberhard, 2003) and elsewhere in the social (Kontopoulos, 1993) and physical sciences (von Bertalanffy, 1968).

3.1 Unification of L1 and L2 Learning Models

The first phrase in the elaboration of the UCM involved dealing with age-related changes in the outcome of second language (L2) acquisition. It is widely accepted that children end up acquiring a second language more completely than adults. One account proposes that there is a "fundamental difference" (Bley-Vroman, 2009) between child and adult L2 learning which arises from the expiration of a biologically-based critical period for natural language learning. In contrast, the framework of the Competition Model emphasizes that all forms of language acquisition make use of the same set of cognitive and social processes, although they differ in the relative reliance on specific processes and the extent to which these processes interact with other learning.

Specifically, the UCM (MacWhinney, 2017b) holds that, when compared with children, adults face greater challenges from these four risk factors:

- The **entrenchment** of first language (L1) patterns (Schmid, 2017) leads to competition with L2 patterns. The role of entrenchment and competition in shaping adult L2 performance was already a major feature of the classic Competition Model (Bates & MacWhinney, 1981; McDonald, 1989). As Zevin (2012) has argued, entrenchment is fundamental property of neural network functioning, rather than a species-specific genetic mechanism of the type involved in critical periods.
- Adults rely heavily on **transfer** of patterns from L1 to L2. Although it facilitates quick success, transfer leads to inaccurate learning, because L1 forms seldom match L2 forms perfectly. In addition to these negative effects of transfer, reliance on translation from L1 creates a parasitic relation of L2 on L1 (Kroll et al., 2010).
- When acquiring new words, adults tend to apply **overanalysis** by isolating content words in phrases without regard to inflections and function words. Children, on the other hand, are more likely to learn language by acquiring words as parts of larger chunks in which inflections and function words are fully encoded.
- Adults may be subject to **isolation** from interactions with the L2 community.

Adults can counterbalance these four risk factors through an emphasis on four protective or preventive factors.

- Adults can learn and consolidate new forms through an emphasis on **resonance**—the process of creating meaningful links between L2 forms (Schlichting & Preston, 2015).
- Adults can bring themselves to think in L2 (MacWhinney, 2008b; Vygotsky, 1934). This process of **internalization** leads to further strenghtening of links between L2 patterns, producing greater fluency.
- When learning new forms and combinations, adults can emphasize **chunking** of large phrasal units (MacWhinney, 1975b, 1982).
- Adults can avoid social isolation and maximize **participation** by reading L2 materials, watching L2 programs, and socializing with L2 groups (Firth & Wagner, 2007).

All of these processes can impact both children and adults. What differs across age is the relative social status of the person and the degree to which they have already consolidated L1. None of these effects arise from the expiration of a biologically-driven critical period for language learning.

3.2 *Levels Analysis*

One of the limitations of the classic Competition Model was its failure to fully consider variation in the learning of different levels of linguistic structures. For example, although adults outperform children in terms of learning of the L2 lexicon, they encounter significantly more problems in acquiring a nativelike L2 pronunciation. To understand these differences, we need to think about language in terms of its component structural levels. Emergentist theory emphasizes three major dimensions that control physical, biological, and social processes. These are competition, structural levels, and time/process frames. The classic version of the Competition Model describes and quanitifies the role of competition in language. In a fuller emergentist account (MacWhinney, 2015a), the analysis of competition must then be supplemented by an analysis of structural levels. For this, we can rely on the fact that structural linguistic analysis (Harris, 1951) distinguishes the levels of input phonology, output phonology, lexicon, semantics, morphology, syntax, mental models, and interaction, as indicated in Table 1.

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, auditory, and perceptual 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,

Table 1 Levels of linguistic processing

Map	Processes	Theories
Input phonology	Extracting units	Statistical learning
Output phonology	Targets, timing	Avalances, gating
Semantics	Imagery	Embodied cognition
Lexicon	Gangs, fields	DevLex, resonance
Syntax	Slots, sequences	Item-based patterns
Mental models	Deixis, roles	Perspective theory
Interaction	Sequencing, affiliation	CA, sociolinguistics

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 (MacWhinney, 1975a, 2014), 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 emerging from the levels of role assignment, space–time configuration, causal relations, and perspective taking. As noted by Chafe (1994) and MacWhinney (1977, 2008a), perspective-taking and perspective-shifting play a central role in linking together models of the actions of agents, positions in space–time, and causation (Talmy, 2000). Articulation of the links between the theory of perspective and the classic Competition Model depend on examination of online cue processing effects, as illustrated in studies such as McDonald and MacWhinney (1995) which examined how verb-based implicit causality established mental models that influence anaphoric binding.

The levels distinguished by structural analysis are richly interconnected. This means that, although they are partially decomposable (Simon, 1962), 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, such as tonotopy (Wessinger et al., 1997) or somatotopy (Hauk et al., 2004).

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 & Hensch, 2014). 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). The details of this analysis can be found in MacWhinney (2017b).

3.3 Time/Process Frames

Emergentist theory also holds that structures emerge from the constraints arising within time/process frames. The operation of frames and their constraints can be illustrated by looking at how a set of four structural levels determine the shape of proteins (Campbell et al., 1999). During protein folding, the *primary structure* of the protein is constrained by the sequence of amino acids in the chain of RNA used by the ribosome as the template for protein synthesis. This sequence conveys a code shaped by evolution; but the physical shape of a specific protein is determined by processes operating after initial RNA transcription. The first partially folded structure to emerge is the *secondary structure* of coils and folds created by the imposition of constraints from hydrogen bonding across the amino acid chain. These forces can only impact the geometry of the protein once the primary structure emerges from

the ribosome and begins to contract. After these second structures have formed, a *tertiary structure* arises from constraints imposed by 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. It is this final structure that allows each protein to serve its unique role, be it oxygen transport for hemoglobin or antigen detection for antibodies. In this partially decomposable emergent system, each level involves a configuration of components from lower levels, but the biochemical constraints operative on each level are unique to that level and only operate once that level has emerged during the process of folding.

The fully emergentist version of the UCM emphasizes the ways in which language learning and processing is constrained by processes operating at divergent structural levels in divergent time/process frames (MacWhinney, 2015a). To account for patterns of disfluency, stuttering, code-switching, and conversational sequencing, we look at the constraints imposed by online lexical access, patterns of cortical activation, and social affiliation. Some of these constraints operate across a timeframe of milliseconds and others, like social affiliation, extend across decades. The UCM distinguishes five major groups of time/process frames: phylogenetic drift in the species, diachronic change in the language, developmental change across the lifespan, memory consolidation across days, and frames for online processing and conversation in the moment. Within each of these five major time/process frame groups there are dozens of component processes working to constrain the shape of language.

The importance of timeframes is illustrated by a particularly puzzling aspect of language learning, which is the way in which young immigrant children can completely forget their first language (Venturcyra et al., 2004). These cases of complete language attrition contrasts with the minimal level of language attrition experienced by older immigrants (MacWhinney, 2018). It is difficult to account for this in terms of entrenchment alone, because the young learners have used their L1 continually for as much as 6 years. Instead one needs to look at the role of social support for young immigrants, pressures to adopt L2, and the role of literacy in helping older learners consolidate their access to L1 forms. Understanding the interactions of these processes requires a model that can bring all of these forces and timeframes together in terms of competition, motivation, and consolidation. Elaborating these effects is now a major emphasis for ongoing UCM research.

4 Conclusion

The classic version of the Competition Model emphasized the ways in which cue reliability shaped cue strength. These effects were measured in highly structured sentence processing experiments. To address certain limitations of this research, the Unified Competition Model sought to account in greater detail for age-related facts in the comparison between child and adult second language learning. Within

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