CHAPTER FOUR

Second Language Acquisition and the Competition Model

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Current approaches to second language acquisition (SLA) can be divided broadly into two groups: nativist models and empiricist models. Nativist models attribute language development to the operation of a universal, genetically controlled, language instinct. For researchers in the nativist tradition, the learning of the core features of a second language involves little more than the setting of a few switches for the parameters of Universal Grammar (Du Plessis, Solin, Travis, & White, 1987; Gregg, 1989; Liceras, 1989; Mazurkewich & White, 1984; Thomas, 1991; White, 1983, 1985, 1990, 1991). Many nativists view second language acquisition as recapitulating the course of first language acquisition (Bickerton, 1984; Krashen, 1982) because a strong version of the nativist position holds that both first and second language learning are determined by the underlying principles of Universal Grammar.

Empiricist approaches to second language acquisition tend to emphasize the extent to which the second language must be actually learned. Some second language researchers who are willing to grant that first language acquisition is strongly influenced by Universal Grammar are not willing to view second language acquisition in the same light (Bley-Vroman, Felix, & loup, 1988; Clahsen & Muysken, 1986; Schachter, 1989). Researchers who accept nativist approaches to first language acquisition and empiricist approaches to second language acquisition often bolster their analysis by pointing to evidence for a critical period for language learning. Johnson and Newport (1989, 1991), for example, have argued that the onset of puberty

marks the end of the critical period for language learning, after which the learner can no longer rely on the forces of Universal Grammar to facilitate the task of second language learning, (See Harley & Wang, chapter 1, this volume, for an up-to-date review of the critical-period literature.)

In this chapter, we explore a position that views both first and second language learning as constructive, data-driven processes that rely not on universals of linguistic structure, but on universals of cognitive strucaire. This model is the Competition Model of MacWhinney and Bates (MacWhin-ney, 1987a, 1989, 1992). The Competition Model presents a functionalist and connectionist view of both first and second language learning that attributes development to learning and transfer, rather than to the principles and parameters of Universal Grammar. We explore how the Competition Model deals with some of the basic facts of both first and second language learning, and we focus on those aspects of the model that allow it to distinguish between the two types of language learning. Before looking at specific studies and specific findings, let us first review the basic theoretical commitments of the Competition Model. These principles are claimed to hold for both first and second language learning.

THE COMPETITION MODEL

The model can be understood best in terms of the commitments it makes to four major theoretical issues:

1. *Lexical Functionalism.* In the debate between functionalist and for malist accounts of language structure and processing, the Competition Model takes the side of functionalist analysis. The basic claim of functionalism is that the forms of language are determined and shaped by the communicative functions to which they are placed. These forms are understood to be either standard lexical items (words) or more complex constructions, such as idioms or fixed phrases. The pressure of communicative function, operating in accord with the constraints of neurolinguistic processing, is considered to be the primary determinant of language development, processing, and evo lution. In contrast, formalism looks at language learning in terms of the system of forms without reference to the functions being expressed by these forms.

2. *Connect ion ism.* In order to model the interactions between lexical mappings, the Competition Model uses connectionist models. Four important properties of these neural network systems are *competition, gradience, emer gence,* and *transfer* (MacWhinney, 1996b). Of these four properties, the most important for understanding second language acquisition is transfer.

3. *Input-Driven Learning.* In the debate between nativism and empiri cism, the Competition Model emphasizes the role of the input rather than innate principles or parameters. The role of the input is treated in terms of the constructs of *cue validity* and *cue strength.*

4. *Capacity.* The use of language in real time is continually subject to potential capacity limitations in terms of short-term verbal memory (Baddeley, 1986; Gupta & MacWhinney, 1994; Potter, 1993). Because of its func tionalist orientation, the Competition Model focuses on the role of underlying conceptual interpretation in determining the utilization of processing capacity.

Together, these four commitments comprise an integrated, minimalist approach that allows us to interpret experimental data with the fewest possible theoretical assumptions and without reference to assumptions that cannot be directly related to observed linguistic, neurological, and experimental facts. In the next sections, we explore these four commitments of the Competition Model in greater detail, with an eye toward understanding what they can tell us about second language learning.

LEXICAL FUNCTIONAIISM

The representational structures utilized in the Competition Model are simple and traditional. The model takes as its starting point the Saussurean vision of the linguistic sign as a set of mappings between forms and functions. *Forms* are the external phonological and word order patterns that are used in words and syntactic constructions. *Functions* are the communicative intentions or meanings that underly language usage. In the Competition Model, each lexical item or syntactic construction can be understood as a form-to-function mapping. Take the word *cat* as an example. The functions for this word involve the expression of the various semantic properties of the animal, along with its visual and auditory images. The form of the word is the set of phonological cues contained in the sound sequence *IkAtl.* In connectionist network diagrams, the association of the sound of *IkAtl* to the concept *cat* involves the connection of one set of nodes to another. The association between *IkAtl* and *cat* is an example of the simplest of lexical items. Other types of lexical associations include collocations, idioms, and extended rhetorical patterns (MacWhinney, 1982, 1985).

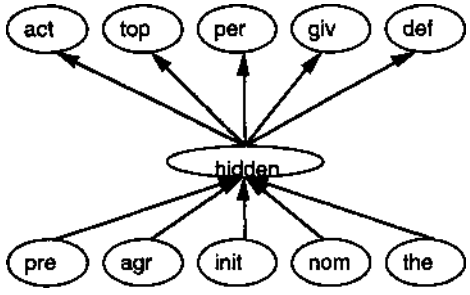
In the version of lexical functionalism developed in MacWhinney (1987b, 1987c, 1988), syntactic patterns are controlled by interactions between lexical items. For example, the relation between the operator *another* and the noun to which it is attached is understood to be derived directly from the semantics of the word *another.* We can say that the word *another* has a role structure with a single empty slot that must be filled by a nominal argument. The

filler of this slot is typically a count noun. If a mass noun is placed into this slot, as in *another sand,* we are forced to interpret that noun as having been semantically extended to act as a count noun. For example, we could imagine that the *sand* in *another sand* is a *bag of sand.*

By linking words together in this way and by adjusting their meanings to fit in with other words with which they combine, we can build all types of phrasal structures. However, the full articulation of a lexical basis for grammar requires the use of connectionist networks to express the syntactic and semantic properties of related lexical items, or "gangs" (MacWhinney, 1989). For example, the semantic and phonological properties differentiating verbs that take double object constructions, such as *give* or *throw,* from verbs that only take prepositional datives, such as *recommend* or *donate,* can be controlled through competing cues in lexical connectionist networks. Analyses of this type have also been developed inside Dependency Grammar (Hudson, 1984) and Construction Grammar (Fillmore, Kay, & O'Connor, 1988). For further details on these issues, the interested reader may wish to consult MacWhinney (1988, 1989, in press).

Much of the cross-linguistic work conducted in the Competition Model framework has focused on the use of cues to agent identification. Figure 4.1 presents a simple connectionist model for the cues to agent identification in English. This network takes as input various combinations of these cues: preverbal positioning (placing *the hoy* before *loves* in *The hoy loves the parrots),* verb agreement morphology (marking *loves to* agree in number with *the hoy* rather than *the parrots),* sentence initial positioning, nominative case-marking for pronouns (7 vs. *me* as a marker of the subject in English), and use of the article *the.* The network produces as output a series of functional interpretations, including actor, topicality, perspective, givenness, and defini-teness. For example, if the input sentence is *The boy loves the parrots,* then the input nodes activated are *pre, agr, init,* and *the.* The node for *nom* is not activated because *boy* is a noun, and there is no case-marking for nouns in English. In this particular case, all five units of the output are turned on. In

FIG. 4.1. A network for relating subject-marking forms to subject-related functions in English.



terms of sentence production, the connections in Fig. 4.1 operate in the opposite direction.

Note that Fig. 4.1 includes an additional layer of connections called *hidden units*. Connectionist models use these additional units to facilitate the learning of nonlinear associations between inputs (functions) and outputs (forms). Nonlinearities arise when cue A has one effect in the presence of cue B but an exactly opposite effect in the presence of cue C. A good example of a nonlinear association is the marking of the English subject. In the active voice, the positioning of the noun before the verb is a clear and unmistakable marker of agential status. However, in the passive voice, exactly the opposite relation holds, with preverbal positioning serving as a cue to the role of semantic patient or theme. This flip-flop between two competing interpretations of the same surface cue is mediated by the presence or absence of the additional cue of passive morphology on the verb. If the verb has the passive morphology, the normal interpretation is reversed. This relation between the cues involved is a good example of a nonlinear association.

The architecture of connectionist systems of the type diagrammed in Figure 1 provides us with several additional ways of thinking about the relations between forms and functions. In a network with a set of hidden units, a group of functions can work in concert to control a set of hidden units that can, in turn, control a set of forms. In fact, hidden units can pattern in a wide variety of complex ways across various combinations of forms and functions. These patterns give us a way of thinking about four basic ways in which language maps forms onto functions:

1. In natural dialog, communicative functions tend to co-occur in a state of *peaceful coexistence*. For example it is often the case that the topic of a sentence is also agential, given, definite, and perspectival. Together, these five functions form a cluster of co-occurring, mutually compatible relations that activate a set of parallel linguistic devices, such as preverbal positioning and unmarked stress. These correlations are reflections of real correlations between properties of the world in which we live. Because the functions we choose to talk about are highly correlated in real life, the forms we use to talk about these functions also become highly correlated. This makes it so that no single form expresses any single function, and the relation between forms and functions is both fluid and complex. There are also important correlations on the level of forms. For example, words that take the article *the* also are capable of taking the plural suffix, and so on (Maratsos & Chalkley, 1980).

2. We can think of a complete set of form-function mappings of this type as a *coalition* of forms and functions. Common grammatical coalitions in clude *subject, complement, subordinate clause, adverb,* and *progressive.*

3. The co-operation that exists in coalitions is balanced by the *competition* that exists between major form alternatives. For example, only one noun

phrase in a sentence can be the agent, and only one can be the patient. This means that there is a direct competition between agent marking and patient marking, as schematized in Fig. 4.2.

Competitions of this type exist on all levels of language processing. Words compete for lexical activation, phrases compete for syntactic ordering position, and sounds compete for insertion into syllabic slots. In comprehension, alternative sound forms compete for lexical activation, and alternative interpretations compete for phrase and case role assignments.

4. All of this co-operation and competition works against a background of probabilistic activations that leads to a system rich in *category leakage.* Leakage arises when a form that is normally associated with a certain function starts to be viewed occasionally as expressing some related, but different function. The root cause of category leakage is the fact that, even before the leakage becomes obvious, there is often no single function that is uniquely associated with a given form. Instead, several allied functions may coexist peacefully because they coexist peacefully in the world around us. For example, it is typically the case that a *causor* is also an *initiator,* and the functions of *causor* and *initiator* tend to coexist peacefully. Over time, the functional weight of a given marking can change so that what was originally a secondary function starts to emerge as the primary function. MacWhinney (1989) examined cases of reinterpretation of this type in the historical development of case-marking in Hungarian. The fact that a particular suffix can be interpreted as marking definiteness in one century and direct object marking in the next illustrates the extent to which language can be seen as a slow-moving dynamic system.

CONNECHONISM

One of the oldest debates in psychology and philosophy is the debate between nativism and empiricism. Nativist accounts are linked to complex theories that make strong claims about biological mechanisms whose psy-

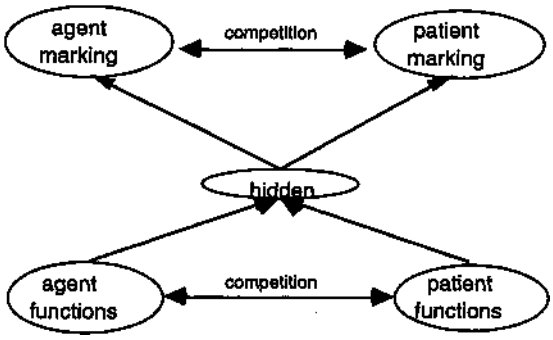


FIG. 4.2. A network illustrating the competition between case roles in English.

chological, genetic, or neurological reality has not yet been demonstrated. Among the various assumptions made by nativist systems, the most problematic is the assumption that the brain is a symbol processing device similar to the serial digital computer. In reality, the brain is not a digital computer, and it has no method for passing symbols down axons and across synapses. Brain waves cannot be used to transmit phrase structures, and there is no evidence that the DNA in neuronal nuclei can encode RAM (random access memory) addresses in the way that these addresses are encoded by digital computers (Kanerva, 1993). Rather, it appears that the brain relies on a type of computation that emphasizes patterns of connectivity and activation. Models based on this type of computation are called *connectionist* models, and they can be developed to offer computationally explicit accounts of second language learning.

Transfer

When we think about bilingual processing, we first need to consider the degree of processing independence between the two languages. The connectionist view assumes that all mental processing uses a common, interconnected set of cognitive structures. This means that the early second language learner should experience a massive amount of transfer from LI to L2. Because connectionist models place such a strong emphasis on analogy and other types of pattern generalization, they predict that all aspects of the first language that can possibly transfer to L2 will transfer. This is an extremely strong and highly falsifiable prediction. However, it seems to be in accord with what we currently know about transfer effects in second language learning.

In regard to lexical processing, connectionist models predict that the initial referent of a new L2 vocabulary item will be the full conceptual structure of the most closely corresponding LI word. The work of Kroll and associates (Kroll & Sholl, 1992) supports this prediction. For phonology, these models predict that LI phonological features will be reconfigured and transferred as the initial basis of L2 segments. This prediction has been supported by work from Hancin-Bhatt (1994), Flege (1987), and Flege and Davidian (1984).

The model claims that the second language learner begins learning with a parasitic lexicon, a parasitic phonology, and a parasitic set of grammatical constructs. Over time, the second language grows out of this parasitic status and becomes a full language in its own right. In the lexicon, this occurs by strengthening of direct associations from the L2 phonological form to the underlying referent and by restructuring of the meanings of some words. If two words in LI map onto a single word in L2, the basic transfer process is unimpeded. It is easy for a Spanish speaker to take the L2 English form *know* and map it onto the meanings underlying *saber* and *conocer* (Stock-well, Bo wen, & Martin, 1965). What is difficult is for the LI English speaker

to acquire this new distinction when learning Spanish. In order to correctly control this distinction, the learner must restructure the concept underlying *know* into two new, related structures.

By building direct links between sound and meaning in L2 and restructuring underlying concepts, the learner is able to build a fire wall against ongoing interference effects from LI to *12*. Consider the case of the English word *table* and the Spanish word *mesa*. The construction of this fire wall in an adult learning Spanish as a second language requires the formation of links between the new Spanish word and other related Spanish words. At the same time, the concept underlying *mesa* will become linked to phrases and meanings that are more closely associated with the Spanish-speaking world than the English-speaking world. The more these two synonymous nouns can be linked into separate worlds and to other words in the same language, the stronger will be the fire wall that can prevent interference. This type of separation must be achieved not only on the lexical level but also on the phonological, syntactic, and semantic levels. In effect, this work undoes the early parasitic association of concepts that the beginning second language learner used to bootstrap the first phases of learning. The end result of this process is the tightening of within-language links in contrast to between-language links. In this way, a certain limited form of emergent linguistic modularity is achieved. For those bilinguals and multilinguals who acquire all of their major languages simultaneously during childhood, these modules are constructed directly, and there is no need to go through a process of undoing the initial connections formed through transfer (De Hou-wer, 1995; Grosjean, 1982).

In phonology, inappropriate interference effects are eliminated by essentially undoing much of the direct transfer of the first period of second language learning. In some cases, new sounds are learned that no longer mirror LI sounds. In other cases, the challenge is to free newly acquired words from sounds influenced by LI segments.

In grammar, the weights connecting functions to clusters of forms must be reamed during second language acquisition. In some cases, the second language requires the learner to seek out entirely new conceptual or discourse distinctions that were ignored in the first language but which are now obligatory grammatical contrasts in the new language. A prime example of this type of restructuring might be the foreigner's attempts to pick up the category structure underlying the two major verbal conjugations of Hungarian. Every time a speaker of Hungarian uses a verb, he or she must decide whether it should be conjugated as transitive or intransitive. Making this choice is not a simple matter. The intransitive conjugation is used not only when the verb is intransitive but also when the direct object is modified by an indefinite article or by no article at all, when it is in the first or second person, when the head of the relative clause is the object within the relative clause, when the direct

object is quantified by words, such as *each, no,* and so on. For example, the intransitive conjugation is used when a Hungarian *says John runs, John eats an apple, John eats your apple, and John eats no apple.* On the other hand, the transitive conjugation is used when the object is definite, when it is modified by a third person possessive suffix, when it is possessed by a third person nominal phrase, and so on. Thus, the transitive, or "definite" conjugation, is used when the Hungarian wants to *say John eats the apple or John eats Bill's apple,* whereas the intransitive is used when saying *John eats an apple.* There are some 13 conditions that, taken together, control the choice between the transitive and intransitive conjugations (MacWhinney, 1989). There is no single principle that can be used to group these 13 conditions. Instead, transitivity, definiteness, and referential disambiguation all figure in as factors in making this choice. This way of grouping together aspects of transitivity, definiteness, and possession is extremely foreign to most non-Hungarians. Not surprisingly, L2 learners of Hungarian have a terrible time marking this distinction; errors in choice of the conjugation of the verb are the surest syntactic cue that the learner is not a native Hungarian.

In order to acquire this new category, the L2 learner begins by attempting to transfer from LI. To some degree this can work. The learner attempts to identify the Hungarian intransitive with the English intransitive. However, the fact that many sentences, with objects, also take the intransitive, if the objects are somehow indefinite, tends to block the simple application of this conceptual structure. In the end, no simple transfer will succeed and the learner is resigned to picking up the pieces of this new category one by one and restructuring them into a working system. Here is an area in which attempts at formal linguistic analysis on the learner's part only make matters worse. If the learner had proceeded like a Hungarian child (MacWhinney, 1974), he or she would have learned the conjugations by generalizing from a rich database of collocations and phrases. The adult needs to amplify this case-based approach to learning with a way of focusing on contrastive structures in which cues are competing. For the adult, such focusing on particularly difficult parts of a grammatical system increases the efficiency of acquisition.

In many cases, the transfer of syntactic patterns from LI to L2 is structurally correct, but pragmatically inaccurate. For example, Trevise (1986) observed that French speakers make excessive use of topicalization structures in English in the form of structures corresponding to left-dislocations, right-dislocations, and *c'est . . . que* in French. Although these structures are all permissible in English, the actual conditions on their usage are far more restrictive than in French. Similarly, Seliger (1989) notes that Hebrew learners of English tend to systematically underuse the passive. He attributes this underusage to the relatively tighter, genre-dependent conditions on the use of the passive in Hebrew. In general, it is clear that simple transfer of an LI structure to L2 is not sufficient to guarantee correct usage because both underutilization and

overutilization can occur until the full conditions governing the use of a construction in L2 are learned.

INPUT-DRIVEN LEARNING: CUES AND CUE-VALIDITY

The basic claim of the Competition Model is that the system of form-function mappings embodied in language-processing networks is acquired in accord with a property we will call *cue validity.* Cue validity is a general construct developed in different ways by different authors, but the single most common interpretation is in terms of the conditional probability that an event X will occur given a cue Y, that is, p(Xl Y). If this probability is high, then Y is a good cue to X. The most straightforward prediction from this initial analysis is that forms with a high conditional probability should be acquired early and be the strongest determinants of processing in adults.

A more complete treatment distinguishes four cue distribution dimensions. We are particularly interested in the ways in which these four dimensions contribute to cue strength as measured in our psycholinguistic experiments.

1. *Task Frequency.* The most basic determinant of cue strength is given by the raw frequency of the basic task. Some tasks are incredibly frequent. For example, the task of locating an object in space is something that we routinely do as frequently as once every second. Other tasks may be quite rare. For example, we are seldom called upon to determine the rotational momentum of planetary bodies. Linguistic tasks are often of intermediate frequency. The task of determining the agent of the verb occurs with virtually every transitive verb. The task of determining anaphoric reference occurs every time a pronoun is encountered. Because most basic linguistic tasks are well above threshold frequency, the dimension of task frequency is seldom an important determinant of relative cue strength. However, in the case of a second language that was used extremely infrequently, task frequency could become a factor determining a general slowdown in acquisition.

2. *Availability.* Within a given task, cues will vary in their relative avail ability. We can call the relative availability of a cue for a given task its *simple availability.* Usually, however, we are interested not just in knowing whether a cue is present but also whether it has any contrastive effect. This is called *contrast availability.* For example, the cue of subject-verb agreement in English is present in almost all English clauses. However, in many sentences, the verb agrees with two or more candidate subjects. In a sentence such as *The cat chases the dog,* the fact that the verb is marked for a singular subject tells us nothing about the status of the subject because both nouns are singular. In this example, the agreement cue is available but not contrastive. However, in the sentence *The cat chases the dogs,* only the first noun agrees

with the verb and the agreement cue is both available and contrastive. This example shows that an available cue is only useful if it is also contrastive. At first, the child picks up cues on the basis of their simple availability. Even in the first months of language learning, the English-speaking child is already paying more attention to word order than his Italian counterpart. This is because word order is more available as a cue in English than in Italian, in part because of the omission of subjects in Italian. During these same months, the Hungarian-learning child is making more use of case-marking than is his German counterpart. Again, this is because of the higher availability of a non-neutralized case cue in Hungarian. Also, within a single language, if there are two ways to mark a given function, the child will first start to use the one that is more available. For example, in Hebrew, the child will first use the inflectional reflexive because it is more common. Only later will the child pick up the periphrastic reflexive (Sokolov, 1989).

3. *Simple Reliability.* The most important and most basic cue validity dimension is the dimension of reliability. A cue is reliable if it leads to the right functional choice whenever it is present.

4. *Conflict Reliability.* In addition to simple reliability, cues can be characterized in terms of their conflict reliability vis-a-vis some other particular cue. For example, we can look at just those sentences in which case-marking and word order contrast in Dutch. Typically, the noun phrase before the modal verb is the subject in Dutch, but, when that noun phrase is an accusative pronoun, then the case cues dominate over the word order cue. Experiments by McDonald (1989) and Sokolov (1988, 1989) have shown that, up to about age 9, children rely primarily on simple reliability as a determinant of cue strength. However, after this age, conflict reliability becomes more important than simple reliability.

Data on Cue Validity

In order to test the impact of these cue dimensions, we have conducted studies in over a dozen languages over the last 15 years. These languages include English (Bates, McNew, MacWhinney, Devescovi, & Smith, 1982; Bates et al., 1984; MacWhinney & Bates, 1978; MacWhinney, Bates, & Kliegl, 1984; Wulfeck, 1988), German (MacWhinney et al., 1984), Hungarian (Bates et al., 1984; MacWhinney & Bates, 1978; MacWhinney & Osman-Sagi, 1991; MacWhinney & Pleh, 1988), Italian (Bates et al., 1982; Bates et al., 1984; MacWhinney & Bates, 1978; MacWhinney et al., 1984), French (M. Kail, 1989; R. Kail, 1992), Arabic (Taman, 1993), Hindi (Vaid & Pandit, 1991), Spanish (M. Kail, 1989), Dutch (De Bot & Van Montfort, 1988; McDonald, 1987a, 1987b, 1989), Russian (Kempe & MacWhinney, 1995, 1996b), Warlpiri (Bavin & Shopen, 1989), Chinese (Bates, Chen, Tzeng, Li, & Opie, 1991; Li, Bates, Liu, & MacWhinney, 1992; Li, Bates, & MacWhinney, 1993; MacWhin-

ney & Osman-Sagi, 199D, Japanese (Kilborn & Ito, 1989), Turkish (MacWhinney, Osman-Sagi, & Slobin, 199D, and Hebrew (Sokolov, 1988).

Most of these studies have used a simple, basic, sentence interpretation procedure. Participants are given a sentence with two nouns and a verb and are asked to say who was the actor. In a few studies, the task involves direct object identification (Sokolov, 1988), relative clause processing (MacWhinney & Pleh, 1988), or pronominal assignment (MacDonald, 1993; MacDonald & MacWhinney, 1990; McDonald & MacWhinney, 1995), but, most often, the task is agent identification. Sometimes the sentences are well formed grammatical sentences, such as *The cat is chasing the duck* Sometimes they involve competitions between cues, as in the ungrammatical sentence **The duck the cat is chasing.* Depending on the language involved, the varied cues in these studies include word order, subject-verb agreement, object-verb agreement, case-marking, prepositional case-marking, stress, topicalization, animacy, omission, and pronominalization. These cues are varied in a standard orthogonalized ANOVA design, with three or four sentences per cell to increase statistical reliability. The basic question being asked is always the same: What is the relative order of cue strength in the given language, and how do these cue strengths interact?

Reliability Determines Strength. These studies have yielded a remarkably consistent body of results. The most important finding is that the order of cue strength found in our experiments with adults always corresponds with the order of cue reliability yielded by text counts from nonexperimental materials in the language. In different languages, we find different cue dominance patterns. In English, the dominant cue for subject identification is preverbal positioning. For example, the English sentence *The eraser hits the cat* is interpreted as having *the eraser* as the agent. However, a parallel sentence in Italian or Spanish, would have *the cat as* the agent. In Spanish, the prepositional object marker *a* is a clear cue to the object, and the subject is the noun that is not the object. An example of this is the sentence *El toro mato al torero (The bull killed to the bullfighter).* No such prepositional cues exist in English. In German, case-marking on the definite article is a powerful cue to the subject. In a sentence such as *DerLehrer liebt die Witwe(The teacher loves the widow),* the presence of the nominative masculine article *deris* a sure cue to identification of the subject. In Hungarian, the subject is the noun not marked by any suffix or postposition. In Russian, the subject often has a case suffix. In Arabic, the subject is identified as the noun that agrees with the verb in number and gender, and this cue is stronger than the case-marking cue. In French, Spanish, and Italian, the presence of an object pronoun can help identify the noun that is not the subject.

Figures 4.3 and 4.4 illustrate the types of empirical data collected in these studies. In Fig. 4.3, we see a comparison of English, German, and Italian in

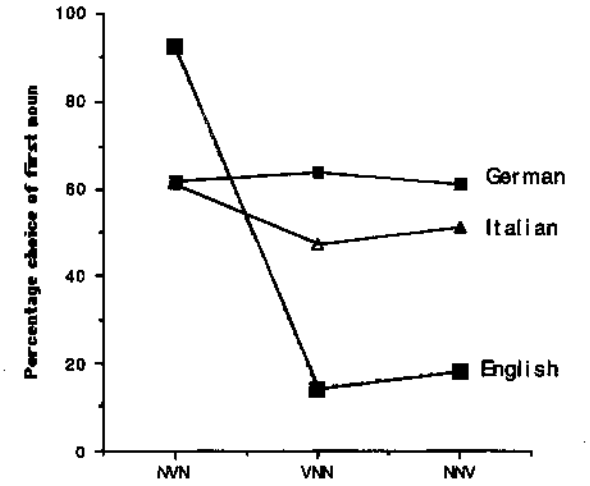


FIG. 4.3. Language x Word Order interaction for English, German, and Italian (Bates et al., 1982).

terms of the strength of use of the preverbal positioning word order cue in adults. In these graphs, percentage choice of the first noun as actor is graphed on the y-axis, with sentence types varied on the x-axis. It is clear that only English makes strong use of the word order cue. When the sentence has NVN order, English speakers interpret it overwhelmingly as SVO, despite the possible presence of agreement or animacy cues pointing in other di-

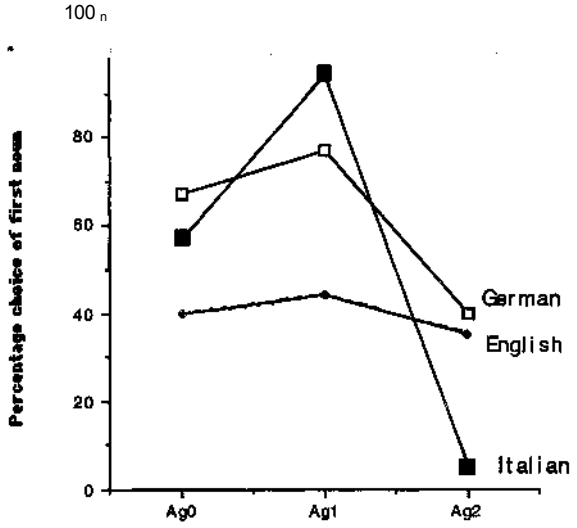


FIG. 4.4. Language x Agreement interaction for English, German, and Italian (MacWhinney et al., 1984).

rections. When the order is NNV, listeners interpret it as OSV, relying on the fact that the noun before the verb is the actor. When the order is VNN, they interpret it as VOS, relying on the fact that the noun after the verb is the object. Germans and Italians make no strong use of any of these cues. In Fig. 4.4, on the other hand, we see that Italians rely intensely on the agreement cue whenever it is present, despite possible contradictory signals from word order or animacy. It is cue usage patterns of this type that indicate the unique footprint of each of the languages we have studied.

Developmental Effects. The Competition Model provides a minimalist, empiricist prediction for the ways in which cues are acquired during first language acquisition. The prediction is that the first cue learned by the child should be the most reliable cue in the language, and the order of acquisition of cues across the span of development should be determined by relative cue reliability. In general, this prediction has held up. Figure 4.5 presents developmental data from three languages. In this graph, we see that word order is the predominant cue for children learning English, and case-marking is the predominant cue for children learning Hungarian. However, we see a major violation of the predictions of the competition model for Italian. If the children were to behave in accord with the cue reliability patterns found in text counts for adult Italians and the cue strengths evidenced by adult Italians, they would make far more use of agreement and far less use of word order. We have interpreted this failed prediction as evidence for additional *cue cost* factors that make it difficult for Italian children to pick up and use the agreement cue. For a further discussion of these issues, see Bates and MacWhinney (1989).

Cue Interactions. In addition to these basic findings regarding primary cue use, we have also found strong support for those aspects of the model that emphasize the ways in which cues interact through strength summation. Traditionally, interactive cue summation has been viewed as evidence for information integration (Anderson, 1982; Massaro, 1987, 1989; Oden & Mas-saro, 1978), and the Competition Model is in accord with information integration theory in this regard. What this means in detail is that when there is a sentence in which the cues for subject disagree then the choice is inconsistent. For example, people might disagree about the identity of the actor in the ungrammatical sentence * *Are pushing the erasers the cat.* In this sentence, the choice of *the erasers* is favored by the agreement cue, but the choice of *the cat* is favored by the animacy cue and the fact that *the erasers* is in object position. In this particular sentence, the crucial preverbal positioning cue is missing, so only weak cues are determining performance. If we look at the sentence *The cats are pushing the erasers,* we have no cue competition at all because agreement, word order, and animacy are now

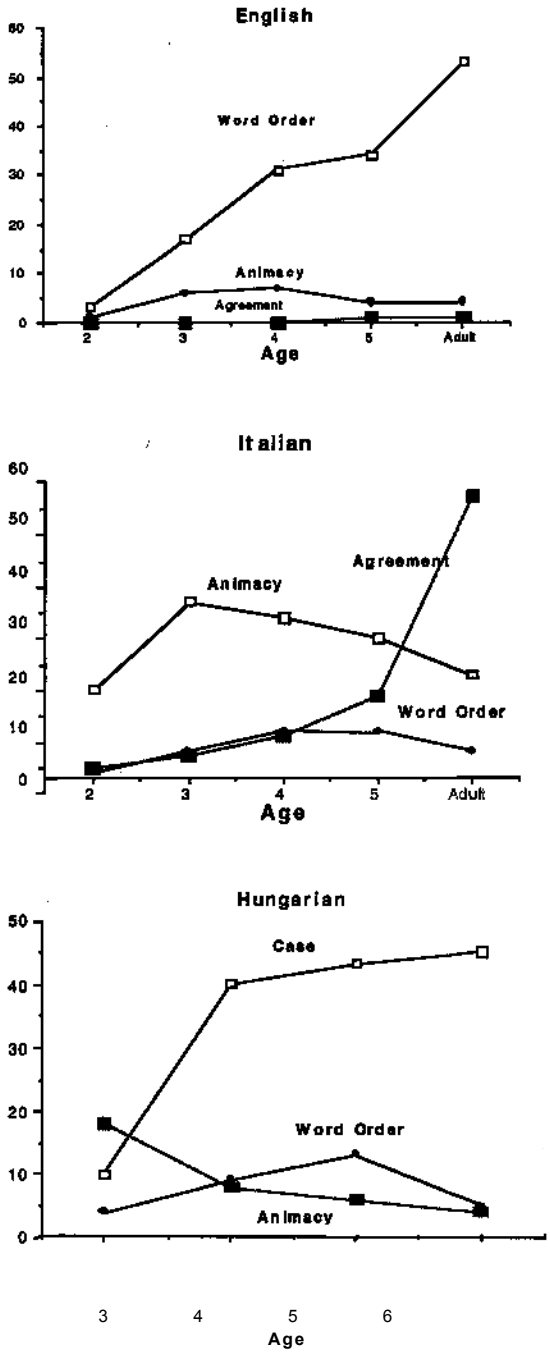


FIG. 4.5. Changes in cue strength through development in English, Italian, and Hungarian. The x-axis in each panel is percentage variance accounted in the ANOVA.

all favoring *the cats*. In general, by looking in detail at cells in which cues either compete or co-operate, we see that the predictions of the Competition Model are uniformly supported in all of this cross-linguistic work.

Mathematical Modeling. These experiments give us data that we can use to compute a numerical cue strength order for each language. This is done by fitting the choice data with maximum likelihood estimation (MLE) models (McDonald & MacWhinney, 1989). If the MLE model can be fit with a small r.m.s.d. (root mean squared deviation), we judge that we have achieved a reliable experimental evaluation of the cue strengths involved. In all of our studies, the r.m.s.d. values are less than 0.05 for our group data. Sometimes the fits are as low as 0.02. To evaluate the basic claim of the Competition Model, we then need to compare these cue strength estimates from the experiments with text counts in which we measure the availability and reliability of cues in naturally occurring sentences. The texts selected for these counts can be novels, parent-<:hild conversations, or foreign language textbooks, depending on the nature of the study involved. In these texts, we estimate availability, reliability, and conflict reliability, using the definitions given above. We usually take reliability to be the default measure of cue validity, although, sometimes, we also factor in availability and conflict reliability when this is motivated by additional theoretical grounds for particular comparisons. Finally, if the relative cue strength hierarchy matches the relative cue validity hierarchy, then we judge the Competition Model predictions to be correct.

Grammaticality Effects. A natural reaction that we find when people are first exposed to some of the ungrammatical sentences used in Competition Model studies is that nothing can be learned about the natural process of comprehension by using unnatural and ungrammatical materials. This reaction is understandable, but unnecessary. The use of unnatural stimuli in psychological experiments has a long and productive history. Much of what we have learned about human perception has been based on the use of illusions and perceptual competitions. In the case of Competition Model studies, we can often demonstrate that the processing of ungrammatical sentences uses exactly the same cues and strategies as the processing of grammatical sentences. For example, in Hungarian, simple transitive sentences without case-marking are perceived as strongly ungrammatical. However, if one of the nouns has the suffix for second person possession, omission of the case-marker is grammatically acceptable. If we compare sentences with and without the second person possessive marking, we find an identical pattern of results for both choice and reaction times. Similar findings for comparisons of this type from Japanese, Croatian, and Italian further support the claim that the processing of ungrammatical sentences

involves the same pattern of cue use found for grammatical sentences. Of course, sentences that obey the canonical patterns of the language, such as SVO sentences for English, are always faster, but this is exactly what we would expect given the notions of cue strength found in the model.

Second Language Studies. Our first investigations of second language processing effects (Bates & MacWhinney, 1981) examined the comprehension of English sentences by a few of our academic colleagues. One participant was a native speaker of German who had lived in the United States for 30 years, was married to an American, and had published several important textbooks in experimental psychology written in English. Remarkably, we found that this participant processed simple English sentences using the cue strength hierarchy of German. This is to say, he used agreement and animacy cues whenever possible, largely ignoring word order when it competed with agreement and animacy. This first evidence for the preservation of a syntactic accent in comprehension has now been supported in over a dozen studies across a wide variety of second language learning situations (Bates & MacWhinney, 1981; De Bot & Van Montfort, 1988; Gass, 1987; Harrington, 1987; Hernandez, Bates, & Avila, 1994; Kempe & MacWhinney, 1995, 1996; Kilborn, 1989; Kilborn & Cooreman, 1987; Kilborn & Ito, 1989; Liu, Bates, & Li, 1992; McDonald, 1987a, 1987b, 1989; McDonald & MacWhinney, 1989).

These Competition Model studies have used the sentence interpretation technique discussed earlier to estimate the strength of cues in second language learners. Because the experimental design places cues into competition, we can use mathematical techniques to estimate the strength of each cue in terms of its ability to determine the shape of our experimental data. We find, uniformly, that the learning of sentence processing cues in a second language is a gradual process. The process begins with L2 cue weight settings that are close to those for LI. Over time, these settings change in the direction of the native speakers' settings for L2. The pattern of results found in this research is perhaps most clearly represented by data from McDonald's studies of English-Dutch and Dutch-English second language learning (McDonald, 1987b). Figure 4.6 shows the decline in the strength of the use of word order by English learners of Dutch over increased levels of competence. In this graph, the monolingual cue usage pattern for English is given in the first column, and the monolingual Dutch pattern is given on the right. Between these two patterns, we see a declining use of word order and an increasing use of case inflection across three increasing levels of learning Dutch. In Fig. 4.7, we see exactly the oppositive pattern for Dutch learners of English. These results and others that are comparable constitute strong support for the application of the Competition Model to second language learning.

A Computational Model. Figure 4.1 depicted a set of connections between forms and functions for the processing of cues to sentence interpretation. It is possible to convert this intuitive analysis of the subject-marking system into an actual running network model. Janice Johnson and I have done this by giving the various surface cues specified in Fig. 4.1 as input to a recurrent network of the type developed by Elman (1990). This network is able to simulate the learning of Dutch and English. The model takes as input a corpus of over 1,000 sentences in each language. This corpus contains grammatical sentences from a wide variety of sentence types, including relative clauses, simple transitives, imperatives, subordinates, pronominali-zations, and grammatical word order variations. After training in either language as LI, the model is given ungrammatical Competition Model sentences as test materials. At this point, we find exactly the types of cue interpretation patterns we saw in graphs, such as Figs. 4.3 and 4.4. In order to model second language learning, we then continue with a period of training with sentences from both languages, and we then see exactly the pattern of cue development reported in Figs. 4.6 and 4.7 from McDonald (1987b, 1989).

Falsifiability. The fact that the Competition Model has often succeeded in predicting specific empirical findings should make us worry a bit. Perhaps it is the case that the model is stated in a way that makes it somehow empirically unfalsifiable. In fact, however, the basic claims of the Competition Model, regarding transfer and cue validity effects in second language acquisition, could be falsified by several types of easily obtained empirical findings:

1. The clearest disconfirmation of the Competition Model would come if we were able to find instances of strong cue use in LI that failed to transfer to L2. Of course, if LI uses case-marking and L2 has no case-marking, transfer is not possible. However, if transfer is possible and does not occur, the model would be strongly falsified.
2. Given the model's emphasis on information integration, failure to find cue summation or competition effects would falsify the model. In L2 learning, cues derive their strength both from transfer and L2 cue learning, but these sources are irrelevant to the measure of cue sum mation effects.
3. Evidence of any sharp discontinuity between grammatical and un grammatical utterances would cast doubt upon our use of the basic Competition Model sentence interpretation task. However, other Com petition Model studies (McDonald & MacWhinney, 1995) that do not use ungrammatical sentences would not be affected by such results.
4. More basically, if we found that, in any language, cue strength was not a function of cue validity, the model would be falsified.

The most promising area for locating falsificatory results appears to be for Point 2. We have some evidence already that, under conditions of speeded online judgments, full cue integration does not occur (Kempe & MacWhinney, 1996b). However, this finding can be accommodated by a revised version of the model that distinguishes optimality in cue use during offline processing from suboptimal cue use during online processing. In effect, this lack of cue integration arises from cue cost factors.

The second falsificatory result that we have collected is the one that indicates a delay in the acquisition of the agreement cue for Italian LI learning. Here, again, we believe that the delay in the learning of the agreement cue in Italian is a result of cue cost or capacity factors that make the processing of the agreement cue particularly difficult.

Sentence Production. Although most of our experiments have focused on comprehension, the Competition Model provides a similar analysis for sentence production. The process of producing a sentence involves the activation of a series of meanings or functions to be expressed. These functions then compete for mapping onto a series of forms for expression. If we are interested in suppressing consideration of the identity of an agent, we use a passive construction and say *The heads were hung incorrectly.* However, if we want to emphasize the existence of a possible perpetrator, we use the active and say *Someone hung the heads incorrectly.* The Competition Model views the production of each sentence as the outcome of a competition between many such alternative forms of expression. In this competition, success is determined by *form reliability.* In production, reliability is defined as the conditional probability of being able to use form X whenever you have idea Y. For example, the preposition *to* is a reliable marker of the indirect object in English. However, the prepositional dative *(I gave the book to John)* competes with the double object construction (*I gave John the book).* The determination of which of these two forms should win is usually dependent on the presence of still other, interacting cues. In this particular competition, the double object wins when there is an additional cue that marks the dative as a pronoun, as in *John ordered her pancakes.* This whole system of activations can be viewed as having the form of the network of Figure 4.1. However, because production works in the opposite direction from comprehension, it is not possible to use exactly the same network and the same set of weights for both processes.

CAPACITY

The fourth major theoretical commitment made in the Competition Model is to a capacity-limited model of language processing. Of course, virtually all models of language processing assume processing limits (Caplan, 1992;

Gernsbacher, 1990; Just & Carpenter, 1992; Martin, 1993). What is unique in the Competition Model approach to this is that the form of the capacity restrictions are tightly related to the connectionist and lexicalist view of processing involved in the first and second theoretical commitments we discussed earlier. However, before examining these relations, let us look at some empirical considerations.

The first 10 years of work on the Competition Model focused on the use of the sentence interpretation task as a way of measuring cue strength. In this task, participants can take as long as they want to answer and are under no time pressure. Beginning around 1988 (Kilborn, 1989; MacWhinney & Pleh, 1988), we began to administer this task with deadlines, asking participants to respond as quickly as possible and measuring their reaction times. More recently, we have used techniques, such as probe recognition (McDonald & MacWhinney, 1995), error detection (Wulfeck, Bates, & Capasso, 199D, and gating (Blackwell, Bates, & Fisher, 1996) as ways of measuring sentence interpretation during online sentence processing.

Although our results for online processing are still far from complete, we now have the outlines of a Competition Model approach to real-time sentence processing. This account treats sentence interpretation as a constraint satisfaction process that balances the limitations imposed by verbal memory against the requirements of conceptual interpretation. Our raw memory for strings of nonsense words is not more than about four. However, when words come in meaningful groups, we can remember dozens of words, even when the message is unfamiliar. The most likely candidate for this additional storage is some form of conceptual representation. Potter (1993) argued that the conceptual aspects of words are available as soon as the words are recognized. We take this point further by claiming that words are quickly converted into integrated conceptual representations through a process of structure building (Gernsbacher, 1990). This process begins with the identification of a starting point (MacWhinney, 1977), or perspective, from which the entire clause can be interpreted. In English, this is usually the subject. As new elements come in, they are linked up to this starting point across *valence bridges*. For example, if the initial phrase of the utterance is *the black dog,* then the noun *dog* is taken as the perspective, and the adjective *black* is linked to *dog* through the modifier valence relation. The formation of the link between *black* and *dog* involves more that the simple positional relation of two words. Instead, the adjective is applied to the noun on the conceptual level, and an image of a black dog is activated. The assumption is that, as soon as verbal material can successfully access an integrated conceptual representation, it no longer exacts an additional storage cost. However, we can isolate at least three possible sources of additional storage costs. These include: (a) blockages to interpretation, (b) perceptual loads, and (c) competition.

Blockages to Interpretation

In some sentences, a full conceptual integration is blocked by the ambiguity of syntactic structures. For example, in the doubly center-embedded sentence *The cat the dog the flea bit chased ran,* we find a stack of three nouns in a row without any binding conceptual glue. In order to relate these nouns to each other, we have to store them in a linear series, wait until we have encountered the string of verbs, and then pull nouns off the series to pair them with the appropriate verbs. This type of positional, nonconceptual processing places heavy demands on raw verbal memory. Even a single center-embedding sentence, such as *The dog that the flea bit chased the cat* involves some storage and restructuring when compared with a subject relative, such as *The dog that bit the flea chased the cat.* Studies of Hungarian (MacWhinney & Pleh, 1988) and Japanese (Hakuta, 1981) showed that the stacking up of unlinked noun phrases can be even worse in SOV languages. Second language learners who have problems coping with such conceptually opaque structures may well have problems with these particular languages (MacWhinney, 1996).

Perceptual Loads

It is easy to interfere with normal language processing by imposing additional loads on the listener or speaker. Kilborn (1989) showed that even fully competent bilinguals tend to process sentences in their L2 more slowly than monolinguals. However, when monolinguals are asked to listen to sentences under conditions of white noise, their reaction times are identical to those of bilinguals not subjected to noise. Similarly, Blackwell and Bates (1994) and (Miyake, Carpenter, & Just, 1994) showed that normals, when subjected to conditions of noise, process sentences much like aphasics not subjected to noise. Parallel results for the effects of noise on simultaneous interpretation have been reported by Gerver (1974) and Seleskovitch (1976).

Competition

The second factor that can influence the success of interpretation in real time is the need to deal with competing interpretations of attachments and role assignments. Consider a German sentence that begins with an initial noun that is ambiguously marked for case, such as *Die Mutter kusst der Vater {The father kissed the mother).* Because the noun *die Mutter* could be in either the nominative or accusative case, the listener does not know initially whether to establish the perspective as agent or patient. Because there is a strong tendency for initial nouns to be agents in German, this reading is favored. However, a cautious listener will continue to maintain the alternative assignment in memory until the clause is complete. There are many examples

of competing interpretations of this type. The parsing model promoted by Frazier and colleagues (Frazier & Rayner, 1982, 1987, 1990) treats ambiguity resolution in terms of garden-pathing rather than competition. However, other researchers (Altmann, Garnham, & Dennis, 1992; Juliano & Tanenhaus, 1993; MacDonald, 1993; Sedlak & Kurtz, 1981; Simpson & Burgess, 1985; Simpson & Krueger, 1991; Small, Cottrell, & Tanenhaus, 1988; Tanenhaus, Carlson, & Seidenberg, 1985; Tanenhaus & Lucas, 1987; Taraban & McClelland, 1988) have found that linguistic processing is best viewed in terms of an ongoing competition between alternatives.

Bayesian Cue Use

In order to characterize the costs involved in maintaining alternative interpretations, the Competition Model extends the notion of Bayesian processing to the use of cues in real time. When cues are used in a nontimed sentence interpretation experiment, the participant has time to perform full constraint satisfaction and to reach an optimal use of each cue, independent of its linear position in the sentence. However, when processing in real time, cues must be used as they occur. In this case, the model makes these assumptions:

1. Each basic cue to sentence interpretation has a *prediction strength* that is distinct from its final *cue strength.* This strength is a function of the likelihood that the use of the cue will be contravened by some other cue that might occur later in the sentence.
2. In adults, each cue's prediction strength is closely tuned to other highly available cues. For example, if a language uses case consistently, then the word order cue will be set to take into account possible reversal by the case cue.
3. Listeners maintain a threshold for selection of an interpretation, based on the summed activation of the cues supporting that interpretation divided by the total activation of all cues.
4. This interpretation selection threshold is variable. When operating un der time pressure, the threshold decreases in order to allow for quick selection of a candidate interpretation.

Recent comparisons of sentence processing in native speakers and L2 learners of German and Russian by Kempe and MacWhinney (1995, 1996b) illustrate exactly how these principles can lead to major differences in cue use in online processing. In these studies, a simple connectionist network is trained with a German corpus and a Russian corpus. The model produces reaction time and choice behavior that is in accord with the experimental data collected from native speakers and adult L2 speakers of each of these two languages.

CRITICAL PERIODS AND FOSSHJ2ATION

Johnson and Newport (1989, 1991) have emphasized the role of critical periods (Lenneberg, 1967) in setting limits to successful second language acquisition (see Harley & Wang, chapter 1, this volume, for a review). They find that some adult learners of English fail to attain even a basic command of syntactic structures if their first exposure to English is in adulthood. For these learners, continued exposure to English does not appear to lead to continued learning. In practice, the language attainment of these learners becomes fossilized or frozen at a fairly low level

Although the studies by Johnson and Newport have problems in design and interpretation (Bialystok & Hakuta, 1994), no one doubts the fact that second language learners often have trouble overcoming transfer effects in phonology and some areas of the grammar. Some authors have tried to use these findings as evidence for parameter setting within a Universal Grammar framework, but the gradual nature of the effortful retuning process in adult second language learners makes it difficult to see how the simple resetting of a parameter can deal with the psychological reality of the difficulties faced by adult language learners.

An alternative view of critical period and fossilization effects focuses on the underlying neural hardware utilized by second language learners. We know that, even during infancy, areas involved in auditory processing and motor control are under intense pressure toward neural *commitment* (Werker, Gilbert, Humphrey, & Tees, 1981). Once a local neural area has been committed, it then begins to accept input data that lead toward a fine-tuning of the activation weights governing processing. If a second language is then to be imposed upon this pre-existing neural structure, it would directly interfere with the established set of weights. In fact, the use of transfer in second language learning allows the learner to avoid such catastrophic interference of L2 back upon LI. However, the parasitic status of L2 cannot be changed without the intervention of additional uncommitted processes. We hypothesize that these additional processes involve the use *of functional neural circuits*for rehearsal, monitoring, and other higher level processes that serve as an external tuning signal upon the weight configuration in the local processing regions. Without this higher level processing, retuning of the local area would not be possible.

Our general picture of the adult second language learner is one that emphasizes the extent to which language learning is no longer supported by the fresh, uncommitted neural hardware available to the child. In addition, the adult often does not have access to the rich system of social support that provides high quality language input to the child (Snow, 1995). Within this natural system of support for language learning, the adult has to construct a system of *autosupport* that uses functional neural circuits and carefully

recruited social contexts as ways of maximizing the outcome of language learning.

CONCLUSIONS

We began by distinguishing two major approaches to second language acquisition. The strong nativist approach emphasizes the role of Universal Grammar in both first and second language development. The strong empiricist approach emphasizes the role of input in both first and second language learning and the role of transfer and generalization in second language learning. We have explored, in some detail, the ways in which one can develop a theoretically consistent empiricist approach that matches well with the available empirical data on second language learning. This approach makes a commitment to four major theoretical positions. First, it views language structure in terms of functional relations that are expressed in lexical constructions. Second, it views processing as arising in connec-tionist neural networks. Third, it views learning as driven by cue validity characteristics of the input. Fourth, it understands capacity limitations in terms of the connections between lexical structures that occur during the process of conceptual structure building.

The wise reader will take these arguments for an empiricist position with a healthy grain of salt. We all know that the most reasonable and tenable positions on major issues, such as nativism versus empiricism, inevitably rest somewhere in the middle between the two extremes. However, it is often helpful to view the competing positions in their most undiluted form, so that we can navigate between these alternatives, coming always a bit closer to the truth.

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