# Chapter 5, Paper 12

# Non-Developmental Studies of Development: Examples from Newborn Research, Bilingualism, and Brain Imaging*

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In this paper we argue that it is becoming increasingly difficult to conceive of *developmental psychology* as a relatively autonomous field of research. Rather, the study of development has become part and parcel of Cognitive Science; it is being pursued in ways that complement studies of children with studies of other groups of subjects.

Cognitive scientists had the tendency to explore how knowledge structures are acquired, focusing on the progress the child makes during learning. In particular, it was Piaget (1973) who claimed that only by studying the unfolding of abilities will psychologists grasp how knowledge is elaborated. Piaget's stance can be best exemplified by remembering how development was approached before the onset of the cognitive revolution. Psychologists attempted to record the behaviors usually

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observed at each age in their hope of extracting from the pattern of change the general model for the elaboration of knowledge structures.

Since the cognitive revolution, scientists working within the rationalist framework promoted by Chomsky (1972), advocated that to build a model of acquisition we must take into consideration the two endpoints of development: the *initial state*, that is, the dispositions organisms have at birth; and the *stable state*, that is, dispositions that adults stabilize in an environment. In this view, development is conceived as a process that maps a species-specific initial state to one of the many possible stable states it can reach.

These are two radically different conceptions of what the study of acquisition ought to be. The first focuses on the observation of the process of growth. The second views development within a learning theoretical framework, that is, within a framework that obliges us to ask what minimal structures a device must have for acquisition to be possible given the environment in which it will stabilize.

The study of language acquisition is particularly complex, because the stable states reached by individuals vary considerably. Indeed, there are thousands of languages that learners may master. We grant that even if all languages share the same abstract structure, the surface differences that exist are sufficiently important to force psychologists to provide a learning account. Moreover, some people learn only one language, others learn two, three and even many more. The fluency displayed by a speaker for different languages may be better or worse than that of another speaker. Some bilinguals are equally good in both languages while others demonstrate dominance in one language. Thus, both formally and sociolinguistically, the description of the stable state gets complicated. From our standpoint, a theory of language acquisition will have to integrate a theory of linguistic competence, that constrains the notion of natural language, and a theory of performance that explains the psychological mechanisms that monolinguals and polyglots put to use when they speak or listen to languages.

In this paper, we wish to make a programmatic suggestion to the effect that it appears more and more difficult to justify studying development through the unique observation of developing infants. Instead, we advocate an approach that integrates observation of initial disposition with the study of functions in the stable state.

We illustrate our point with studies showing how unexpected abilities in the newborn are uncovered, not by pure observation, but by considerations of how a universal initial state can possibly map onto a language-specific stable state. Second, we show that it is possible to improve our understanding of development by studying how second languages are represented in adult bilinguals as a function of the age of acquisition of the second language (L2). Using some simple examples, we argue that studying how languages are represented in the cortex of the bilingual speaker supports our point. Finally, we turn to a more general point discussing our views on learning and development. In the following section, we illustrate a case where data on the newborn infant raise new questions for language acquisition.

## BOOTSTRAPPING LANGUAGE ACQUISITION IN A MULTILINGUAL ENVIRONMENT

To the best of our knowledge, children never fail to learn a language because their parents switched indifferently between two languages (as is often the case in Brussels, Catalunya, Barcelona, or in large parts of the Asian and African Continents). Although satisfactory comparisons are not available, let us informally admit that the bilingual child suffers no acquisition delays.[1] If so, how does the baby escape confusion when the input provides contradictory phonological, prosodic, and phonotactic information? Word boundaries in French can be deduced from the accent which is always in the last syllable of a word, a fact that would be lost if a child were raised with French and another language. Indeed, simultaneous exposure to French and, say, Spanish will not only cancel the advantages of exclusive exposure to French but should add a source of considerable confusion to the learning child.

Recently, statistical mechanisms were proposed to explain aspects of acquisition. Goodsitt, Morgan, and Kuhl (1993) and Saffran, Aslin, and Newport (1996) suggested such a mechanism to explain how the child learns the lexicon of her language. The authors showed that the transition probability between syllables is used to segment the potential words in the message. These beautiful experiments show how the regularities in the linguistic environment can be used profitably by the young child. However, such statistical computations would simply collapse if there were more than one language spoken in the environment and if the infant were incapable of determining the heterogeneity of input. Indeed, the infant would collect statistics that are a mixture of the statistics of the languages in the environment, which would give rise to a complete confusion. Such problems also arise in other frameworks, for instance, Principles and Parameters. Confronted with two languages at once, say, French and Turkish, how is an infant to decide how to set, for example, the head direction parameter? Thus, absence of delays in multilingual settings is problematic for many if not all theories of language acquisition.

To address this issue, we proposed (Mehler, Dupoux, & Segui, 1990) that humans are equipped from birth with a specialized device that allow them to detect the linguistic heterogeneity of the surrounds and classify utterances according to a source language. If this is correct, this provides a way to escape confusion in a multilingual environment, and learn language nonetheless. Mehler et al. (1988) showed that, indeed, four-day-old infants have a remarkable ability to discriminate utterances that belong to their maternal language versus utterances in a foreign language. Such ability remains when the signal is low-pass filtered at 400Hz but vanishes when the utterances are played backward. This indicates that discrimination rests on rhythmical or prosodic properties. It was also suggested that newborns can discriminate between two unknown languages. This study illustrates how learning theoretic considerations can trigger the discovery of abilities in the newborn. But, vice-versa, further study of the newborn can raise issues relevant to acquisition.

For instance, Nazzi, Bertoncini, and Mehler (1998) have recently explored the issue of the resolving power of the initial language discrimination ability. They reasoned that if languages are discriminated on the basis of rhythmical/prosodic properties, there must exist pairs of languages that are very difficult to discriminate—because they have similar rhythmical/prosodic properties. Indeed, Nazzi and colleagues found that while French babies discriminate Japanese from English (two prosodically dissimilar languages), they fail to discriminate Dutch from English (two prosodically similar languages).

Abercrombie (1967), Ladefoged (1975), and Pike (1945) have proposed that languages fall into a small number of prosodically defined classes. Linguists like Beckman and her students have proposed to base classifications in terms of units. Beckman and Edwards (1990) point out that prosody viewed as *the organizational structure that measures off chunks of speech into countable units of various sizes* (Tohkura, Vatikiotis-Bateson, & Sagisaka, 1992) may be the way to improve classification. For linguists such as Dauer (1983), languages map into a continuum rather

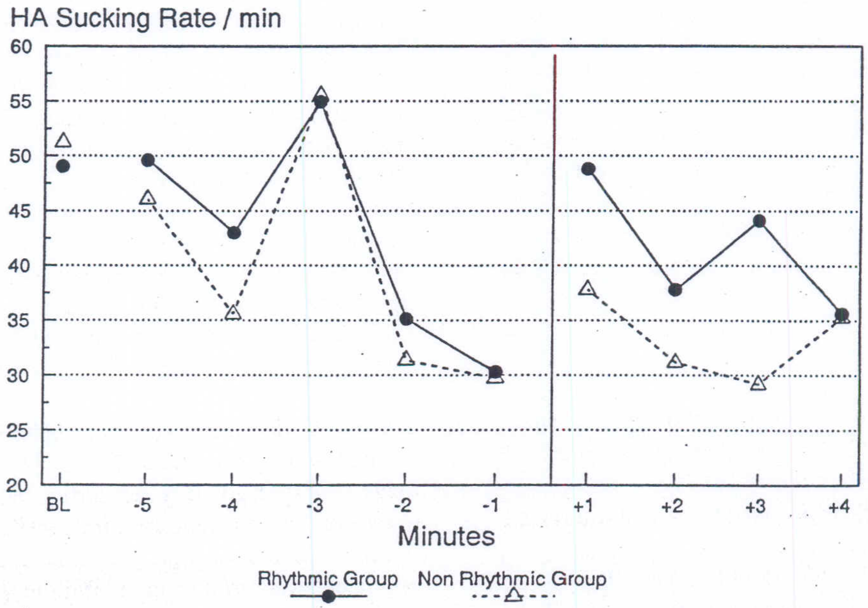


**FIGURE 1. Newborns sucking rate averages during baseline (BL), last 5 minutes of familiarization (-5 to —1), and 4 minutes of test (+1 to +4) for experimental and control groups. The bars above and below each point indicate the standard error of the mean. Experimental groups hear during familiarization a set of sentences that belong to the same language class (i.e., Italian and Spanish, or English and Dutch), and during test switch to a set of sentences in the other class. Control groups hear during familiarization two languages that do not belong to the same class (i.e., Italian and English, or Spanish and Dutch) and during test switch to the other two languages.**

than a discrete space. These proposals are all relevant in order to understand the behavior of very young infants.

In order to evaluate the rhythmic-prosodic hypothesis more closely, Nazzi and Mehler designed an experiment to test whether languages belonging to the same class will be put into the same category at an early stage of development. They habituated infants to a mixture of Spanish and Italian utterances and tested them with a mixture of Dutch and English utterances. Spanish and Italian are syllable-timed languages while Dutch and English are stress-timed languages. The control group was habituated with a mixture of utterances from two different classes (i.e., Italian and Dutch) and tested with a mixture from two different classes (i.e., Spanish and English utterances). As Figure 1 shows, there was a significant difference between the experimental and control groups.

These results lend support to the ability of the very young infant to segregate utterances, possibly not by language, but certainly by broadly defined linguistic family types. It is not yet clear how this discovery meshes with the notion that so much about ones language is learned by statistic calculations. At any rate, this is an important problem for future studies. For instance, it invites one to study acquisition separately in bilingual learners of languages that belong to the same class versus different classes. Cumbersome and lengthy as research with infants may be, it provides a unique situation to understand bare processing. As such, it yields important data on language acquisition.

Let us now turn to a case where the sole investigation of adult populations allows us to test hypotheses about language development in the young infant.

## STUDYING EARLY LANGUAGE DEVELOPMENT THROUGH ADULTS

Studies of language development have uncovered a number of important landmarks in the acquisition of language (babbling, lexical explosion, etc). Recent investigations have demonstrated that infants acquire important phonological properties of their maternal language between 6 month and 12 month of age (see Jusczyk, 1995, for a review). However, observing the unfolding of language abilities in the young infant is not the only way to study how language is acquired. Indeed, there are a number of issues that can most profitably be studied only by looking at adults. For instance, Johnson and Newport (1989) studied groups of adult bilinguals who migrated to the United States at various ages. They reported that mastery in English was related, not to length of exposure to English, but rather to the age of arrival in the United States. This study suggested that acquisition of a second language is easier for young infants than for adolescents. It is consistent with other studies showing that if the maternal language is not learned in the first years after birth it will not be fully mastered (Grosjean, 1989; Mayberry, 1993; Poizner, Klima, & 1987). This, in turn, raises the issue of the existence of a critical period for language learning, a highly relevant question for language development (see Lenneberg, 1967).

Recent research has demonstrated that language processing in the adult is heavily related to the maternal language. Adults perceive speech sounds through the filter of the phoneme categories of their native language: nonnative phonetic contrasts are very difficult to discriminate if they fall within a native category (Best, 1994; Goto, 1979). But there is more to phonology than just segments. Indeed, segments blend into larger units like syllables and feet. Syllables can have structures that differ across languages. Strong evidence exists that both production and perception are sensitive to such higher level properties. Recent results illustrate this in an experiment where we compared French and Japanese speakers. On the one hand, Japanese is a regular Consonant-Vowel language while French allows consonant clusters. On the other hand, Japanese contrasts long and short vowels while French does not. Our experiments showed that the French are very poor judging vowel length but could cope with consonant clusters while the Japanese displayed the reverse pattern (i.e., they are highly sensitive to vowel length but insert an epenthetic vowel into consonant clusters, presumably to yield the familiar Consonant Vowel structure, (as consonant cluster are illegal sequences in Japanese). This result obtained with a simple ABX task is illustrated in Figure 2.

Cutler and her colleagues have also provided us with a number of interesting demonstrations of such a foreign accent syndrome (Cutler & Mehler, 1993; Cutler, Mehler, Norris, & Segui, 1992; Cutler & Norris, 1988). Indeed, the claim is that phonological regularities of the language are used, not only to represent speech sounds, but also to segment the continuous speech stream into discrete words. While native English-speaking subjects use the distinction between strong and weak syllables to postulate word boundaries, French subjects would rely more on syllable boundaries, and Japanese subjects would rely on *moraic* units. Let us assume that these few studies are sufficient to invite the reader to admit, albeit temporarily, that languages are processed in ways that reflect the regularities of the maternal language. The question then is how does such specificity come about? In other words, how does the child learn that the language spoken by adults has to be processed with routines like: *expect CV alternation and moras* if the language is Japanese; *expect syllables and stress in the last syllable of words* if it is French and so forth? This issue that will be examined in detail below exemplifies how developmental issues may be answered by studying adults. Indeed, issues related to the plasticity of acquisition can often be explored and understood by adults who have mastered knowledge at different times during development.

As we said above, it is well known that people experience difficulty learning a new language after puberty (see Johnson & Newport, 1989; Lenneberg, 1967; Oyama, 1976). When someone learns a second language well enough to communicate with native speakers, he generally displays a foreign accent. From a processing perspective, it can be argued that having a foreign accent is parsimonious. If phonemes in a foreign language resemble those in the native language, why not

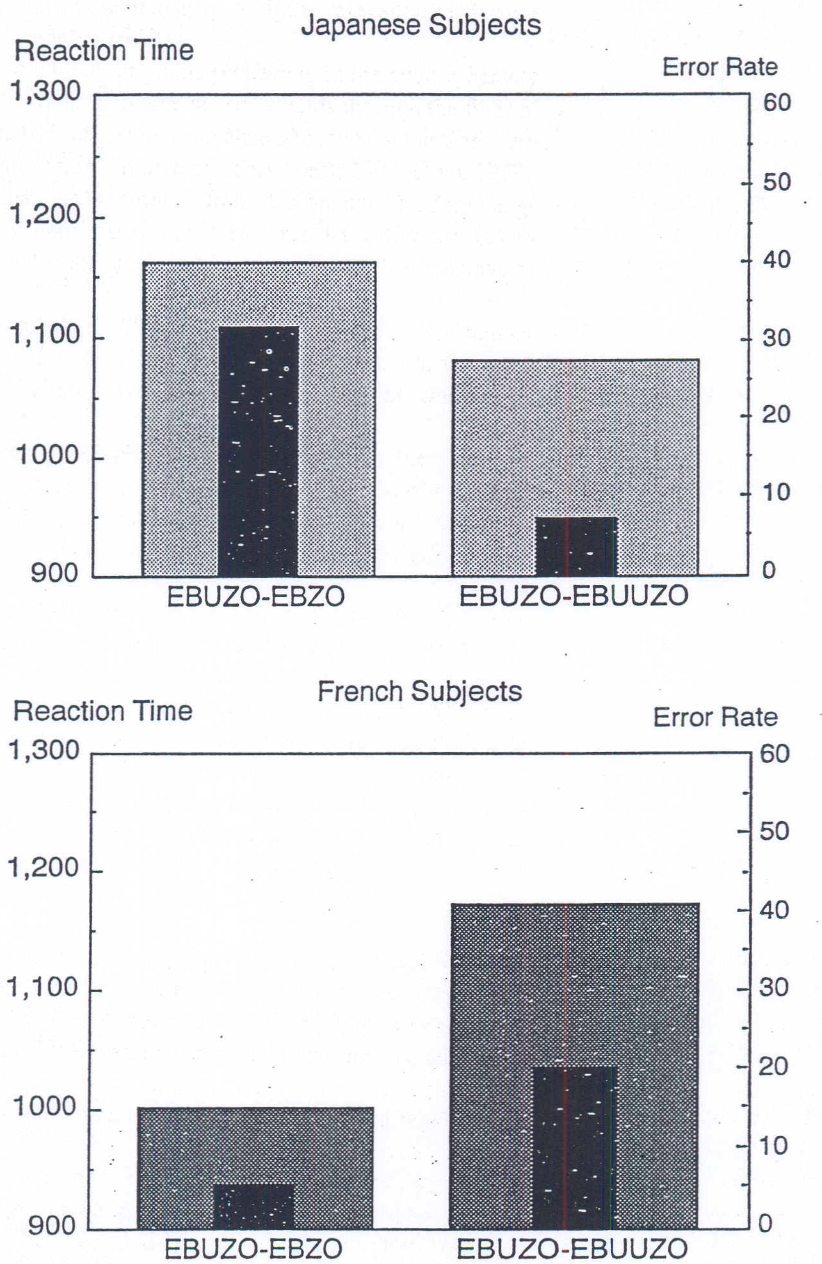


**FIGURE 2.** Reaction time (in gray) and error rate (in black) in an ABX task involving stimuli that vary in the amount of /u/ vowel. The top panel shows the performance of Japanese subjects; the bottom panel shows the performance of French subjects.

use them to encode the unfamiliar sounds? Werker and Tees (1984) have shown that 10- to 12-month-olds tend to neglect segments that are not pertinent to the language spoken in their environment, although they were able to process them for a few months after birth. Best (1994) has proposed that the changes in perceptual behavior observed in young infants arise from the emergence of categories specific to the maternal language. Best's conjecture is that the baby will tend to assimilate a minimal pair to a category that has become functional in the maternal language in order to facilitate processing.

Both Best and Werker predict that competences are never completely lost. Consequently, after a training period, people ought to learn contrasts that were ignored prior to training. Indeed, a number of experiments have documented the virtues of retraining (Pisoni, Aslih, Perey, & Hennessy, 1982). Notice, for example, that Japanese speakers who have lived abroad for many years can produce the /r/ versus /l/ contrast reasonably well. The issue, however, remains whether training renders the participants identical to comparable native speakers. Indeed, when one says that through training participants master this or that contrast, one usually claims that they are performing much better than untrained subjects. If one asks, however, whether late language learners can attain a performance like that of natives, the answer seems to be negative. Striking results collected over the last few years provide a rather bleak view of the capacity to improve through training (Flege, Munro, & MacKay, 1995a,b). Such results correspond better to our experience in the environment of mobility and migration in which we live. We must acknowledge, however, that not all aspects of language are equally difficult to learn after puberty. For example, phonology, and certain parts of syntax, are more difficult to master than the lexicon and semantics (Weber-Fox & Neville, 1996).

Pallier, Bosch, & Sebastian (1997) have studied a population of Spanish/Catalan bilinguals in Barcelona. These subjects have lived and spoken Catalan and Spanish for most of their lives, yet one of the languages was heard much more frequently than the other over the first four years of life. After the age of four, these participants used both languages with equal frequency up to the time of testing. Likewise, their primary and secondary education was fully bilingual. On the surface, one might think that these speakers spoke and understood both languages with the same ease as natives of either of the languages. However, Pallier and colleagues found that this was not true, at least in as far as the phonological component goes. Pallier et al. studied the organization of the vowel space for this population. Spanish has only one vowel in the neighborhood of /e/ while Catalan has an open and a closed vowel in the same space (/e/ vs. /e/). Pallier et al. (1997) tested participants after having classified them as Catalan- or as Spanish-dominant on the basis of the language they heard most frequently during the first years of life. After the age of five, all participants used the languages similarly and had a bilingual education.

The findings by Pallier and collaborators show that the categorization function for the Spanish-dominant subjects is flat throughout a synthetic vowel continuum over which the Catalan-dominant subjects have two categories. These results suggest that the vowel space is determined at an early age, even when infants have some exposure to a competing phonology, and extensive exposure after the age of four. If these results are correct, then we have to conclude that even when one learns language in a bilingual milieu after the age of four, subjects acquire one of the phonologies and apply it to the other language. Very often, when listening to an early bilingual, one may think that they pronounce the nondominant language as if they were monolinguals. Possibly, this belief arises from a charitable way of listening rather than to the real performance of the bilinguals.

The above findings illustrate the use of studying adult populations to understand the plasticity of the components that allow language acquisition. However, a great addition to the study of the biological foundations of language comes from new and recently introduced brain-imaging methods. Are maturational aspects responsible for foreign accents, problems with morphology, and so forth that limit the proficiency when a second language is learned late? Below, we will review some of the results obtained with brain-imaging methods, mostly on bilinguals. We will try to convince the reader that these studies, even if they are carried out with adults, are as much part and parcel of a theory of development as are the studies with infants that we presented in the previous paragraphs.

## BRAIN PLASTICITY AND LANGUAGE ACQUISITION

Over the last decade, a number of powerful brain imaging techniques have made it possible to study the cortical activity of participants while they are performing a task. The availability of these methods has increased exponentially over the last 10 years and great progress is being made. However, before describing results that directly concern us, a word of caution may be necessary. Brain imaging techniques cannot be used like a thermometer one buys in the drugstore or a pressure gauge at the gas station to measure air pressure in tires. Rather, these methods, like any of the other ones available to the psycholinguist, must be carefully calibrated before their use becomes truly instructive. One learns to use the techniques by developing adequate models of how the device measures information processing and by understanding the parameters that affect it. Regardless of the reservations some authors have expressed (see Poeppel, 1996), imaging has already enabled us to carry out experiments that one could not even have conceived of, let alone run, a few years back.

In the late 1980s the first rigorous studies exploring the cortical representation of words in healthy participants captured the attention of psycholinguists. In one study, Participants were instructed to read from a screen while they were being scanned with a Positron Emission Tomography device (see Petersen, Fox, Posner, Mintun, & Raichle, 1989). A few years later, Mazoyer et al. (1993) explored brain activity in subjects while they listened to sentences in either their maternal language (French) or in a language that they had never heard before (Tamil). Listening to the French story yields a pattern of activation similar to what most neuropsychologists would have predicted.[2] In contrast, the activation observed for Tamil was restricted to the mid-temporal areas in the left and right hemisphere.

From the above studies, one cannot conclude whether the activation of the left hemisphere network while listening to French stories arises because French is the native language of the volunteers or because the subjects were attending to stories they understood. Tamil, however, is a foreign language and that might explain the impoverished cortical response observed. Let us imagine that our volunteers had been native speakers of French capable of understanding Tamil: Would they have displayed a similar pattern of activation for the story in L1 and in L2? To explore this question, Perani et al. (1996) studied native speakers of Italian who understood English moderately well. Perani and colleagues found that the activation for Italian is very similar to that previously observed with French volunteers listening to French. When the Italians listened to English, we observed a rather poor and symmetrical activation. In the same study, participants had been asked to listen to stories in Japanese, a language they are unable to understand. Two control tasks had been used: one was listening to Japanese backward and the other listening attentively to silence (which could be broken by the presentation of isolated vowels).

The areas that are more active when listening to Japanese than to Japanese backward are the left inferior frontal gyrus, the left mid-temporal gyrus and the inferior left parietal lobule. Interestingly, those areas have all been, at one time or another, related to phonological processing. Could this mean that the brain distinguishes between a signal produced by the vocal tract and a signal that the vocal tract cannot produce, regardless of the amount of learning? This is a possibility we have considered, but which we cannot yet endorse for lack of corroborating studies.

One could imagine that the areas that are more active when listening to English stories than to the Japanese stories might provide information about the cortical areas devoted to processing lexical, syntactical, and semantic information. Of course, those processes are engaged only when one is listening to a language one understands and not for an unknown language. Thus, we expected to see widespread activation for English as compared to Japanese. Paradoxically, no areas were significantly more activated in response to English than to Japanese in all subjects. At first glance, this result suggests that something may be amiss with our results since we know that the volunteers were able to answer correctly the questions about the English stories although they had no idea of the contents of the Japanese stories. If so, why is it that our studies have failed to find the areas related to the English lexicon, syntax, and so forth? Several conjectures can be invoked to explain this result. First, perhaps languages activate cortical loci regardless of the understanding of the subjects. This seems unlikely given the results from the study by Mazoyer et al. (1993) who found that none of the *linguistically relevant* areas of the left hemisphere were particularly responsive to Tamil, a language the French did not understand. Second, perhaps the Italian volunteers' English was so poor that its cortical representation is similar to that of Japanese? That seems farfetched given the behavioral data. Third, the statistics used to analyze our results may provide some clues to understand what is happening.

Let us consider the following situation: In response to L1, all participants displayed increased activity in the same cortical loci. Let us, furthermore, grant that in response to L2, volunteers display activity in variegated areas of the cortex, and these areas are not the same for each of the volunteers. The comparison of L1 and L2 would then show that some cortical loci that are active in L1 are not active for L2. However, suppose that when volunteers listen to an unknown language (Japanese) the activity is just less important for all volunteers. Then, the direct comparison of L2 and L3 may not show any area that is significantly more activated for L2 than for L3 (nor the reverse). This may be what occurred in our experiment. Such an outcome could arise under the following circumstances: When one learns L1 in infancy, the same cortical resources are engaged. In contrast, when one learns L2, one needs to recruit other areas of the cortex that remain available. Moreover, while the first language is learned by everyone alike, L2 is learned in very different ways by each individual (some learn it at school, some during vacations, and others through friends). If we are correct, Italian ought to be represented and processed in the same way by all native speakers of Italian; English, in contrast should be distributed in a more variable fashion in the cortex of Italian bilinguals. Possibly a good story, but how could one evaluate its validity?

Dehaene et al. (in preparation) attempted this by using fMRI with eight French volunteers who also spoke English. The participants were French–English bilinguals comparable to the Italian–English bilinguals reported by Perani et al. (1996). Participants listened to a story in alternation with backward speech. The story was either in English or in French. French, the maternal language of the volunteers, gave rise to similar patterns of cortical activity in all volunteers. A similar set of areas grouped around the left superior temporal sulcus was activated by L1 in all the volunteers. In contrast, English gave rise to a more variable network of left and right cortical areas. It would be incorrect to state that there was no overlap in activity for L2 among the participants in the study. However, it is the diversity of cortical responses to L2 among participants that is the single most striking outcome of this study. The results of this study mesh well with the conjecture we made to explain the results in the above PET scan study. All these studies up to this point concern volunteers who learned L2 rather late and attained a moderate level of proficiency. What would be observed with participants who had learned L2 late but attained high levels of proficiency, or early in life, also attaining high proficiency? Perani and colleagues are in the process of studying this question. They are testing two populations. The first population is composed of Italians who have learned English with great proficiency after the age of 12. The second population is composed of Spanish–Catalan bilinguals who have acquired L2 quite early in life with great proficiency. Although these studies remain incomplete, they serve to illustrate our purpose, namely, that of broadening the conception we have of the field of development.

The brain-imaging studies reviewed above must not be taken as an attempt to persuade colleagues to stop their research with babies using traditional methods such as head-turning. Rather, we are trying to bring to the attention of our colleagues investigations that can only be carried out with adult subjects. Indeed, PET is an invasive method and fMRI is so noisy that neither one is currently advised as a tool to investigate young children. However, with adult participants these methods are starting to clarify how the brain learns natural languages at different ages. Such information may become very important to construct causal accounts of language development and acquisition. Of course, we are aware that much of this is in the domain of hope rather than achievement. However, we are also convinced that understanding the potential tools offered by Cognitive Neuroscience may be essential to ensure better progress in studying growth and development.

## STUDYING DEVELOPMENT

The study of development originates with the notion that growth, per se, contributes little or nothing to learning, the essential mechanism for acquiring knowledge. Indeed, in his Principles of Psychology, James (1890) does not even have a separate entry to cover the area of development. Neither do we find more than a passing mention of this concept in the textbooks in use during the early 1950s and before. It is only after researchers like Dewey (1910) and Piaget (1937) captured the imagination of psychologists that the area of development began to gain its *droit de cité*. So, what are the essential aspects of development that makes it a notion that we wish to uphold and preserve?

First, we wish to argue that some acquisitions are made possible by the human brain rather than by the brain of any higher vertebrate. If so, such acquisitions cannot be accounted for by a learning device common to humans and other vertebrates. Second, if there are skills for which there is a certain age when acquisitions can be attained in a more natural manner, we might challenge the notion that one and the same learning device operates equivalently at all stages of life. If so, we would want to privilege the study of acquisitions in conjunction with its time course. We suspect that such a study might provide us with an excellent indication of maturational processes in the underlying neural structures.

Our position contrasts with the notion that to understand the acquisition of mental abilities it is necessary and sufficient to study growing children only. It is the "sufficient" part that we challenge. We are interested in discovering the engine or engines that are responsible for development. We do not believe, however, that to discover such an engine, it is sufficient to just measure and report all the things that children of a certain age do and fail to do one year earlier. Indeed, memory span, perceptual constancy, growth of lexical knowledge, and so forth provide examples of properties that have been shown to *develop* or grow with age. Although such measures may partially constrain models, they have not been very helpful in understanding the engines responsible for the observed change.

To recapitulate, the approach that we favor must necessarily take into account data from other disciplines that students of development have had a tendency to neglect. Neuropsychology has made many discoveries that are essential to the understanding of development, and presently brain-imaging studies may offer new vistas to research on growth and development. Thus, rather than making the study of development an autonomous part of cognition, we try to include it as one tool to improve cognitive psychology.

## CONCLUDING REMARKS

The theoretical writings by Chomsky (1959), Fodor (1975) and others have outlined the incapacity of traditional learning models to explain the emergence of most cognitive faculties. These authors have advanced arguments showing that to understand how the human infant acquires language, and many other mental capacities, much more powerful learning algorithms need to be explored. Indeed, they have argued that a better understanding of the biological constraints and the modular organization of the learner must be the basis to establish future theories of acquisition. This is something many learning theorists today admit (Changeux & Dehaene, 1989). If correct, this would count as an additional argument against the belief that observation of growth, by itself, may suffice to explain the causes of change. The faith many psychologists have in observation may have been exaggerated. We do not understand, say, madness, growth, or happiness by just looking at the mad, at children who are growing, or at happy-go-lucky fellows. What we need are theories of the underlying causes of change, and we need to test their empirical predictions. That is something that generative linguists and cognitive psychologists have done in the last 20 years.

Generative grammarians and psycholinguists who have tried to explain how language is acquired have espoused a theory that takes the following form: Assume that some part of the recursive machinery underlying grammatical behavior is one-and-the same, regardless of the natural language that will be stabilized by the learner. The theory of acquisition one has to postulate to explain why only humans acquire natural language is called Universal Grammar, and it is the recursive machinery referred to above. Once such a theory becomes sufficiently well specified, it gives rise to learning models that can be tested in detail. For instance, in the case of language, one of the most studied domains of cognitive science—parameter setting—is precisely such a model. Its aim is to explain how with speech as input the learner obtains the grammar that is adequate for the language spoken in her background. Exciting work as to how parameter setting works have begun to appear (Fodor, personal communication; Gibson & Wexler, 1994).

In parallel with those theoretical developments, we have tried to argue that the discovery of the nature of the representation of language in the mind of adults instructs us about the learning opportunities licensed by different time frames and different socio-linguistic contexts. Thus, the use of brain imaging technology has allowed us to demonstrate that the maternal language is mediated by a network in the left hemisphere. This network may be dedicated to the acquisition and representation of the maternal language (second languages can be learned with more or less success). What is clear is that learning a language late in life is difficult and that its cortical representation is less reliable than for L1. Our investigations corroborate reports by Neville and her collaborators. In numerous papers, they have suggested that when one learns a language after the age of six, proficiency will be significantly lower than that of an early learner. Moreover, Mayberry (1989, 1993) has demonstrated that even when the first language is learned after a certain age, it will be mastered with less proficiency than languages that are learned in the crib. All these investigations, using different tools and different domains of observation, corroborate that language is learned best within a narrow temporal window.

The above paragraphs should not be read as meaning that language cannot be learned with great skill late in life. We know that languages can be mastered late with sufficient skill such that no one but the expert can notice inappropriate use of L2. However, from our perspective, the fact that differences remain between the performance of an adult who has spoken a second language, say for 40 years, and an adolescent who has spoken the same language, his native language for, say 15 years, is a critical piece of evidence. It suggests that frequency of use and habit cannot explain all aspects of language acquisition.

Moreover, language acquisition raises the issue of behavioral plasticity that is relevant to other faculties of the human mind. Indeed, Cognitive Neuroscience illustrates unambiguously the amazing plasticity of somatic-sensory maps in young and adult organisms. At the same time, Psycholinguistics has demonstrated the lack of plasticity in our ability to acquire high level skills like language after puberty. How does one come to terms with such a contrast between plasticity in mechanism and rigidity of function? Should we consider the findings of neuroscience and ignore behavior or, conversely, should we focus on behavior and consider the cortical processes at some later time? Or have we become sufficiently wise to consider data from both fields and try to integrate them into a realistic model of how acquisition actually works? That, as we have tried to illustrate, is our conception.

We hope that the introduction of proper methods and adequate theoretical perspectives will allow both Cognitive Science and Cognitive Neuroscience to jointly address the above issues jointly and solve some of the problems that have been so difficult for either discipline to solve by itself. We tried to raise some examples of what such a course might look like. We take it that the course that is emerging shows the way toward a better understanding of development without focusing exclusively on growing organisms during the few years after birth.

## NOTES

[1] For all we know, some very minor delays might exist although they would not require a radical change of our argument.

[2] There are some areas (e.g., the anterior poles of the temporal lobes and Brodmann 8) that had not often been related to language processing by classical neuropsychology.

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