16 Age Effects in Language Acquisition and Attrition

Christophe Pallier

The notion that children are especially gifted at learning languages, compared to adults, is certainly not revolutionary. For example, the French philosopher Michel de Montaigne (1533–1592) reported that, when he was a child, his father only hired servants who could speak Latin and gave them strict orders to always speak this language to him or in his presence. The aim, of course, was to maximize the chances of making the future philosopher become fluent in Latin. The notion that "the younger, the better" concerning language learning is widespread in the general public and has been invoked to justify the introduction of foreign language education in elementary schools in many countries. Interestingly, research has shown that adults actually outperform young children in the first stages of second language learning (Krashen, Long, & Scarcella, 1982), and that the benefits of early exposure to foreign language in the classroom are far from obvious (Burstall, 1975; Singleton & Ryan, 2004). Yet, it remains undeniable that the age of acquisition of a language, at least in naturalistic situations if not in the classroom, is clearly negatively correlated with eventual proficiency, especially for phonological and grammatical skills (for reviews see Birdsong, 2005; Hyltenstam & Abrahamson, 2003; DeKeyser, 2000).

Understanding the basis of the age effect on language acquisition is important not only for theoretical but also for practical reasons. One popular explanation is that the brain of young children is especially "plastic" and that, under the influence of maturational factors, this plasticity progressively diminishes, resulting in essentially stable language circuits. This notion found a staunch advocate in the Canadian neurosurgeon Wilder Penfield, who claimed that "for the purpose of learning languages, the human brain becomes progressively stiff and rigid after the age of nine" (Penfield & Roberts, 1959, p. 236). Going further in his book *Biological Foundations of Language*, Lenneberg (1967) developed the theory that language acquisition in humans was subject to a critical period. More precisely, he proposed that the human brain was equipped with specialized mechanisms to acquire language that functioned only during a certain time window. According to Lenneberg, these mechanisms start working around 2 years of age and "after puberty, automatic acquisition from mere exposure to a given language seems to disappear, and foreign languages have to be taught and learned through a conscious and labored effort" (p. 176.) Sensitivity to language input would have the shape displayed in Figure 16.1A. Steven Pinker (1994, p. 294) expressed a similar view and reasoned that "once a language is acquired, the neural machinery for language acquisition can be dismantled as keeping it would incur unnecessary metabolic costs."

It must be noted that, in the literature, one often encounters upper age limits for the critical period that are lower than those advanced by Lenneberg or Penfield. For example, 6 years is often mentioned as the upper age limit for the acquisition of an accent-free second language (e.g., Long, 1990). Pinker (1994, p. 293) stated that "acquisition of a normal language is guaranteed for children up to the age of six, is steadily compromised from then until shortly after puberty, and is rare thereafter" (the age function would have the shape depicted in Figure 16.1B). There is actually evidence that even starting to learn a second language as early as 4 to 6 years of age does not necessarily ensure nativelike levels in speech production or perception (Flege, Munro, & MacKay, 1995; Pallier, Bosch, & Sebastian-Gallés, 1997), nor even in grammatical processing (Weber-Fox & Neville, 1996). Effects of age are therefore present even before 6 years. Concerning the closure of the critical period, empirical data on second language (L2) acquisition provide little evidence for a discontinuity at puberty. Birdsong (2005) convincingly argued that the age effects on L2 extend after puberty (and maybe across the whole life span; see Hakuta, Bialystok, & Wiley, 2003) and essentially decrease in a monotonous fashion, as shown in Figure 16.1D.

If the age effect on L2 acquisition is really due to an irreversible loss of neural plasticity under the influence of maturational factors (i.e., a decline in neuronal or synaptic density with age), then the conclusion is clear: it is critical to expose children to new languages as soon as possible. The research reviewed in this chapter will show that the reality is more complex.

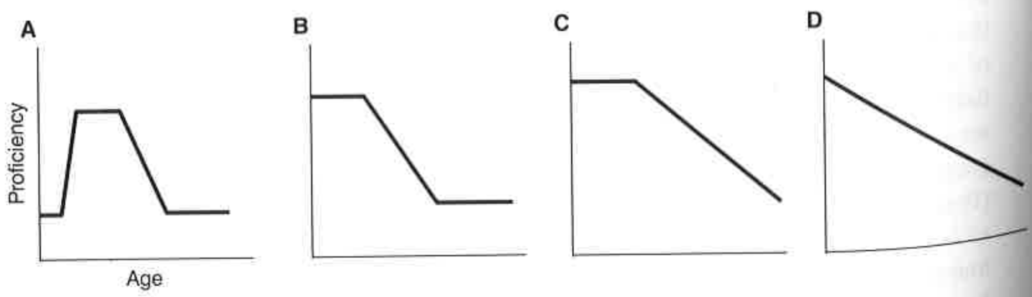

Figure 16.1
Various potential relationships between age of exposure and ultimate attainment in a language (adapted from Birdsong, 2005)

Early Sensitivity to Language

In 1967, Lenneberg proposed that the onset of the critical period for language acquisition was around 20 months of age. At that time, only the speech-production behavior of children was easily accessible to investigation. In the ensuing years, research looking at the perceptual capabilities of children, initiated by the discovery of Eimas et al. (1971) that 1-month-old infants could discriminate phonetic contrasts, established that infants are sensitive to language much earlier and that learning starts from birth and even in the womb. For example, it was shown that neonates (1 to 4 days old) prefer to listen to their mother's voice (DeCasper & Fifer, 1980; Mehler, Bertoncini, Barrière, & Jassik-Gerschenfeld, 1978) and to their maternal language (Mehler et al., 1988; Moon, Cooper, & Fifer, 1993). During the first year of life, infants become attuned to the phonology of the ambient language(s), learning the phonemic repertoire (Werker & Tees, 1984; Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992), the phonotactics (Jusczyk, Friederici, et al., 1993), and the prosodic characteristics (Jusczyk, Cutler, et al., 1993). At the babbling stage, starting around 8 to 10 month of age, the productions of babies are already influenced by the language spoken in their surroundings (De Boysson-Bardies, Sagart, & Durand, 1984). At the end of the first year, they start to associate words and meanings (Hallé & De Boysson-Bardies, 1994). The profile of sensitivity depicted in Figure 16.1A, with an onset at 2 years, is no longer tenable: there is no evidence that language acquisition is, as it were, "switched on" at a given time point. Yet, one important question remains concerning whether these early abilities reflect language-specific or general learning mechanisms; the debate has not been completely resolved (see, e.g., Elman et al., 1997). At the very least, the behavioral studies suggest that human infants are innately attracted to speech signals (Colombo & Bundy, 1983; Jusczyk & Bertoncini, 1988), which makes sense from an evolutionary perspective.

The definite answer to the question of whether the human brain is hardwired to process speech will ultimately come from brain studies. For the moment, very few functional brain imaging studies on infants exist (Dehaene-Lambertz, Dehaene, & Hertz-Pannier, 2002; Dehaene-Lambertz et al., 2006; Peña et al., 2003). Their main conclusion is that the infant's brain does not respond diffusely to speech but relies on the same perisylvian network of areas as in adults, with some left-hemisphere dominance already apparent.

Peña et al. (2003) and Dehaene-Lambertz et al. (2002) presented recordings to young infants in their maternal language. The first study used functional magnetic resonance imaging (fMRI) with 3-month-old babies, while the second used near-infrared spectroscopy (NIRS) with neonates. The same utterances were also presented backward, yielding sounds that are as complex as speech but cannot be produced by a vocal tract and violate universal prosodic rules. The NIRS captors showed stronger activity over the left hemisphere than the right when neonates listened to forward speech compared to backward speech. The anatomically more precise magnetic resonance technique showed activations in the left temporal (superior temporal gyrus) and parietal (angular gyrus) regions. Moreover, the latter region reacted more strongly to forward speech than to backward speech, as did a right prefrontal region in the awakened children (some of the infants were asleep in the scanner, while others were awake).

Using fMRI again, Dehaene-Lambertz et al. (2006) presented short sentences to 3-month-old infants. As in the previous experiment, activations were detected in the temporal lobes bilaterally (with more activation in the left hemisphere than in the right). Active clusters were also found in the right and left insula and in the left inferior frontal gyrus, as typically observed in adults. The stimuli were played at a slow pace that allowed the authors to examine the temporal delays of the brain responses. The analysis of these delays revealed an adultlike structure: the fastest responses were recorded in the vicinity of Heschl's gyrus, whereas responses became increasingly slower toward the posterior part of the superior temporal gyrus and toward the temporal poles and inferior frontal regions (Broca's area).

In brief, the cerebral activations in very young infants listening to speech are remarkably similar to those observed in adults; they are not limited to unimodal auditory regions and extend to remote frontal regions, which used to be considered barely functional at this age. This observation refutes the theory of progressive lateralization of language advanced by Lenneberg (1967). According to him, both hemispheres were responsive to speech at the onset of the critical period and the maturational process made the left become progressively dominant over the right. Functional brain imaging studies of language comprehension show bilateral activations, both in children and in adults, with a relative left dominance. It must be stressed, however, that data currently available on infants remain quite scarce. Despite the results with backward speech, it is too early to categorically claim that there are brain areas that respond specifically to speech and not to other types of sounds of similar complexity.

Effect of Delay on First Language Acquisition

Most humans are typically exposed to language(s) from infancy and learn it (them) without difficulty. Only a few reports exist on children who grew up in extreme social isolation and received very little language input until puberty. Itard (1964) described the case of Victor, the "wild boy of Aveyron," who was discovered running naked in woods in the south of France when he was about 12. With the help of his instructor, he acquired a rudimentary vocabulary and learned to respond to simple written expressions, yet he never learned to articulate speech properly. (Because he had a

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throat wound, it is not clear if this reflected a cognitive limitation.) More details are known about the case of Genie (Fromkin, Krashen, Curtiss, Rigler, & Rigler, 1974; Curtiss, 1977). Genie was found at the age of 13 after having suffered extreme social deprivation. She became able to understand and produce speech, acquired a fair amount of vocabulary, and was able to build sentences. Yet she failed to achieved normal linguistic competence after many years of training. For example, she continued to form negative sentences by putting *no* at the beginning of sentences. Her case suggests that limited language acquisition is possible after puberty (for another case of relatively late L1 acquisition (after 9 years), see also Vargha-Khadem et al., 1997). However, it must be acknowledged that in Genie's case as in Victor's, little is known about their early experiences with language, which makes it difficult to draw strong conclusions.

More extensive data come from studies on deaf adults who learn sign language at different ages (Newport, 1990; Mayberry & Eichen, 1991; Mayberry & Fischer, 1989). Many deaf children are born to hearing parents and, for the most part, are not exposed to a full-fledged language until they enter schools for the deaf and learn sign language. This line of research has shown that, even if sign language can be learned at any age, there are clear effects of age of first exposure on the ultimate proficiency: the earlier deaf students were exposed to language, the better they perform in various language tasks (memory for sentence and story, shadowing, sentence and story comprehension, and grammatical judgment tasks). According to Mayberry (1998, p. 8), delayed acquisition of sign language affects the processing of "both simple and complex syntactic structures and impacts all levels of linguistic structure, namely, phonology, morphology, the lexicon, syntax, and semantics."

This age effect on ultimate proficiency in L1 begins quite early. Newport (1990) found that children who began learning sign language at age 4 did not perform as well as those exposed to sign language from birth. Studies of auditory and language development in congenitally deaf children who receive cochlear implants (an auditory prosthesis that stimulates the auditory nerve in order to transmit acoustic information to the central auditory system) reveal that behavioral benefits of early implantation can be observed even in the range of 1 to 3 years of age (McConkey Robbins, Burton Koch, Osberger, Zimmerman-Philips, & Kishon-Rabin, 2004; Tomblin, Barker, Spencer, Zhang, & Gantz, 2005). Measuring auditory evoked potentials, Gilley, Sharma, and Dorman (2008) found that their topography was influenced by the age of implantation, suggesting a cortical reorganization with age.

Are endogenous maturational factors the only cause of the age effect on L1 acquisition? This hypothesis can be rejected. A study by Mayberry, Lock, and Kazmi (2001) clearly established the major role of *deprivation*—that is, the fact that the deaf children who did not learn American Sign Language (ASL) in infancy were deprived of normal linguistic input in their first years of life. The authors compared two groups of deaf adults who had both learned ASL relatively late, between 9 and 15 years of age. ASL was the L1 for the participants of the first group, who were congenitally deaf. Participants in the second group were born with normal hearing and had started to acquire English before they became deaf. Therefore, ASL was their L2 (note that the grammar of ASL differs markedly from the grammar of English; Klima & Bellugi, 1979). Mayberry et al. (2001) found that the second group largely outperformed the first in ASL. If only maturational factors were at play then the proficiency in ASL should only depend on age of acquisition of ASL. Mayberry et al.'s results demonstrate the crucial role of early experience with language.

The studies on the effect of delay on the acquisition of an L1 demonstrate that linguistic deprivation has rapid detrimental effects on ultimate proficiency. Because deprivation is the usual test applied to assess critical periods in animals, it appears undeniable that there is a critical period for normal first language acquisition in humans. This may be an instance of *experience-expectant* plasticity as defined by Greenough et al. (1987): the immature brain expects "language" in the environment. In the absence of linguistic stimulation, the brain areas that normally subserve language processing may either deteriorate or be recruited for other functions. This last interpretation is supported by data from Lee et al. (2001) showing that the benefits of cochlear implantation are inversely related to the amount of metabolism in the temporal lobes. In other words, the deaf who have "abnormally" low metabolism in the temporal region (before receiving cochlear implants) profit more from implants than those who have higher metabolism, presumably because in the latter case, these areas are recruited for extralinguistic functions (see also Neville & Bavelier, 2002).

Effect of Delay on Second Language Acquisition

As mentioned in the introduction, research has confirmed the view that the age of acquisition of a second language is a potent factor for ultimate attainment (for reviews see Long, 1990; Birdsong, 1999; DeKeyser & Larson-Hall, 2005). Unlike the situation with L1, the age effect on L2 cannot be explained by a lack of language input in the first years of life. Incidentally, Mayberry (1998) noted that the effects of age are less dramatic for L2 than for L1 acquisition, suggesting that different mechanisms may be at play.

Some versions of the critical period hypothesis claim that, after puberty, a second language is acquired in a fundamentally different way than the first because the brain circuits for language acquisition are no longer operational. This predicts, then, that L1 and L2 should be supported by (at least partially) different brain areas.

This view is not supported by brain imaging studies on the cortical representations of L1 and L2 in bilinguals (for reviews see Perani & Abutalebi, 2005; Pallier & Argenti, 2003). In studies using fMRI or positron-emission tomography (PET), the patterns of activation elicited by the use of the first or the second language are quite similar for the two languages in highly proficient bilinguals, and this is little affected by their age of acquisition. In less proficient bilinguals, L2 sometimes provokes stronger or more diffuse activations than L1 in classic language areas but there is no clear evidence for L2-specific brain areas. Considering data from bilingual aphasia as well, Paradis (2004) concluded that a bilingual's language subsystems are represented in the same cerebral areas at the macroanatomical level. Given the current resolution of brain imaging techniques (about 2 mm), it is quite possible that L1 and L2 are differentiated at the microanatomical level, but the main fact remains that a second language, even acquired late, does not rely on fundamentally distinct brain systems from the first language. This result refutes a version of the critical period hypothesis, according to which the circuits that support L1 have lost plasticity and L2 must be supported by different circuits.

Language Loss

The hypothesis that the neural circuits subserving language lose plasticity predicted that the effects of learning a language in the first years of life should be irreversible. In the same way that one never forgets how to ride a bicycle, one should therefore never forget one's maternal language.

International adoption provides a way to assess this idea. The overwhelming majority of foreign children adopted in new families stop using their maternal language (Maury, 1995; Isurin, 2000). Pallier et al. (2003) contacted organizations in charge of international adoption and managed to recruit a small sample of young adults born in Korea who had been adopted by French-speaking families. They came to France when they were between 3 and 8 years old and had not been exposed to Korean since then. All claimed to have completely forgotten Korean (though some had memories of their life in Korea).

Three behavioral experiments were designed to assess their residual knowledge of the Korean language. The adoptees' performances was compared to that of a control group of native French speakers who had never been exposed to Korean, nor to any Asian language. The Korean sentence identification experiment involved recognizing sentences in Korean among recordings in different languages. In the word recognition experiment, subjects heard two Korean words and had to choose which was the translation of a given French word. Lastly, in the speech segment detection experiment, the task was to decide if speech fragments were present in sentences in various languages, including Korean. The results show similar patterns of performance for the adoptees and for the control group of native French speakers, validating the adoptees' claim that they have largely forgotten their first language.

While the subjects performed the speech segment detection task, their brain activity was monitored using functional magnetic resonance. The analyses of fMRI data showed, for each of the adoptees, no detectable difference in brain activity when comparing the cerebral responses to Korean sentences versus Japanese or Polish sentences, two languages to which the adoptees had never been exposed. Thus, brain imaging data and behavioral data converge in the conclusion that years of exposure to a language in childhood are not sufficient to maintain a solid knowledge of this language.

This result can be interpreted in two different ways. First, the Korean language may have been "erased" from the brain of the adoptees. This would constitute strong evidence against versions of the critical period hypothesis that state that some "neural connections" become fixed in the early years of life, as a result of learning and/or because of maturational factors. These hypotheses predicted that the adoptees (at least those arriving at older ages) should have displayed a considerable sensitivity to Korean. It must be noted, however, that because the subjects arrived in France before the age of 10, we cannot exclude the possibility that irreversible changes occur at puberty.

A second possible interpretation is that the paradigms used in Pallier et al., (2003) lacked sensitivity and that further testing may uncover effects of the early exposure to Korean. With Valerie Ventureyra, I ran a series of behavioral experiments to more thoroughly test the remnants of Korean in the adoptees (Ventureyra, 2005). In a nutshell, we found virtually no significant difference between the adoptees and native French speakers. For example, the adoptees were not better at perceiving the differences between Korean plain, tense, and aspirated stop consonants, a phonemic contrast in Korean (Ventureyra, Pallier, & Yoo, 2004).

One important question is whether the adoptees could relearn their native language faster or better than people who have never been exposed to Korean. This would provide evidence for remnant traces of early exposure to Korean. From an anecdotal point of view, the adoptees who visited Korea for short stays (from a few days to a few months) did not miraculously "recover" the ability to speak or comprehend the language, nor did the few of them who attended Korean lectures.

There is some evidence that early exposure to a language leads to an advantage when one relearns it later (Tees & Werker, 1984; Oh, Jun, Knightly, & Au, 2003; Au, Knightly, Jun, & Oh, 2002; Knightly, Jun, Oh, & Au, 2003; Au, Oh, Knightly, Jun, & Romo, 2008). For example, Oh et al. (2003) evaluated the perception and production of Korean consonants by three groups enrolled in Korean language classes: one group had spoken Korean regularly for a few years during childhood, another group had heard Korean regularly during childhood but had spoken Korean minimally, and the last group consisted of novice learners. The first two groups performed better than the novice learners, demonstrating long-term benefits of early childhood experience with Korean.

Au et al. (2008) tested adult learners of Spanish who had spoken Spanish as their native language before age 7 and only minimally, if at all, thereafter until they began to relearn Spanish around age 14 years. They spoke Spanish with a more nativelike accent than typical late L2 learners. On grammar measures, although far from reliably nativelike, they also outperformed typical late L2 learners. These results suggest that while simply overhearing a language during childhood could help adult learners speak it with a more nativelike phonology, speaking a language regularly during childhood could help relearners use it with more nativelike grammar as well as phonology.

As mentioned above, it would be highly desirable to know whether the adoptees also have "dormant traces" of the language they have been exposed to in their childhood. In the relearning studies cite above, the subjects were not completely severed from the language of interest. For example, in the Oh et al. (2003) study the nonnovice subjects overheard Korean on average 4 hours per week. Therefore, their situation was quite different from that of adoptees who have not been exposed at all to Korean since adoption. Whether the adoptees would relearn their first language faster than novice learners remains an unsolved empirical question. Nevertheless, the studies on adoptees that show the ability to comprehend a language can be lost suggest that the "plasticity" of the language-learning system is considerable up to the age of 10 years.

Conclusion

I started from a seemingly simple idea: that the brain is especially "plastic" in very young children and that, under the influence of maturational factors, this plasticity is progressively lost, resulting in an essentially stable adult brain. Instead, the research reviewed in the chapter suggests that

- When children are not exposed to a first language in the early years of life, their language acquisition is compromised: they are not going to master a language like native users. However, this effect is not simply a maturational effect but is a consequence of an "abnormal" experience: linguistic deprivation in the early environment (Mayberry et al., 2001). One putative explanation is that the brain circuits for language are reused for other functions (Lee et al., 2001).
- There are indisputable age effects on ultimate proficiency in the second language (L2). However, the shape of the age effect on L2 is more or less linear and does not show a clear discontinuity (Hakuta et al., 2003; Birdsong, 2005). It certainly does not have the same origin as the age effect on L1 because L2 learners have not been

deprived of any language input and their brain has, presumably, developed in a "normal way."

• Studies on internationally adopted children suggest that it is possible to lose understanding of a first language, even after 10 years of exposure. There is therefore still considerable plasticity in the language circuits until that age. An interesting observation it that studies on language loss in adult immigrants show much less dramatic forgetting (Köpke & Schmid, 2004; Köpke, 2004), maybe reflecting changes in brain plasticity around puberty.

• In babies, the same brain areas are activated by language as in adults, undermining the notion of progressive lateralization put forward by Lenneberg in one version of the critical period hypothesis.

• Brain imaging studies (PET or fMRI) of bilinguals found that they rely on the same macroanatomical brain areas to process L1 and L2 even when L2 has been acquired after L1, as long as proficiency in L2 is high (Perani & Abutalebi, 2005). This refutes a simple version of the critical period hypothesis, according to which the brain circuits underlying L1 have lost plasticity and L2 must be learned by different circuits.

Data on first language acquisition demonstrate that there is indeed a critical period for language acquisition in humans in the sense that a lack of language stimulation in the early years has irreversible consequences. This critical period for a first language does not explain the effect of age on second language acquisition, inasmuch as second language learners have not suffered from linguistic deprivation in childhood. The effects of age on second language learning, which begin early, are unlikely to involve simple maturational loss of plasticity, because plasticity is still considerable at 10 years of age, as studies on adoptees show.

The reality is therefore considerably more complex than entailed by a simplistic notion of maturational loss of plasticity. Yet, one must recognize that the critical period hypothesis for language acquisition has generated, and is still generating, a lot of research that has improved our understanding of the mechanisms of language acquisition.

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