CHAPTER 17

AGE AND THE END STATE OF SECOND LANGUAGE ACQUISITION

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In contrast to child first language acquisition (L1A), the typical outcome of postadolescent second language acquisition (L2A) is nonnativelike attainment. However, some adult learners at the L2A end state perform like natives in psycholinguistic experiments. A number of age-related factors are thought to influence learners' potential for nativelike attainment in L2A. Data from L2 learners at the end-state figure prominently in major themes in L2A research, such as the critical period hypothesis for L2A (CPH/L2A), L1 influence, neurocognitive and neurobiological aging, and L1 versus L2 processing.

I. THE L2A END STATE

A. The Construct of End State

The outcome of language acquisition is often referred to as the *end state*. This term should not be understood in an absolute sense. In the native language, there is no "end" to the accumulation of vocabulary items (including regionalisms, neologisms, slang, and idiomatic expressions) over the course of a person's lifetime. Among L2 users, the pronunciation, lexis, and syntax of the L1 are subject to ongoing assimilation to the L2, as is also conspicuously the case with L1 intrusions into the L2 (see discussion in section V regarding L1–L2 reciprocal influence).

While such examples indeed illustrate the dynamic nature of linguistic systems, linguists commonly posit an idealization of finality with respect to the development of the underlying grammatical system of a language. On this view, most of the abstract features of L1 syntax, phonology, and morphology are stably represented in the minds of speakers at some point prior to adulthood. It is this knowledge that many linguists refer to when they use the term end state or its synonyms *steady state* or *final state*. Psycholinguists often use the terms *asymptote* or *asymptotic attainment* to accommodate the idea that there may be a practical end, but no absolute finality, in the development of linguistic knowledge and language processing ability.

In the L2A context, the term *ultimate attainment* is commonly substituted for end state. Though sometimes erroneously used in reference to nativelikeness, ultimate attainment refers to any and all L2A end points, up to and including nativelikeness.

B. Studying the L2A End State

In the literature on late L2A (defined in this contribution as immersion in the L2 around adolescence), the traditional emphasis is on "failure." Failure is understood as an L2A end state that is measurably different from the end state of L1A. Studies too numerous to mention have revealed L1–L2 differences; however, many studies showing differences do not concern learners at the L2A end state.

Another perspective emphasizes the variety of L2A outcomes among individual learners. These range from telegraphic speech, to functional adequacy in everyday situations, to sounding like native speakers. Bley-Vroman (1989) points out that a primary goal in L2A research is to explain why there is such uniformity of outcome at L1A end state and such diversity at the L2A end state.

A third perspective focuses on learner potential. What are the upper limits of L2 attainment? Despite well-studied impediments to learning, late L2 acquisition is not doomed to result in failure. Nativelike levels of proficiency in pronunciation, morphosyntax, and processing have been documented in the literature, and some adult L2 learners attain nativelikeness across multiple challenging tasks (see section VI).

An individual learner's potential is not directly revealed by pace of acquisition (e.g., the length of training required to reach a learning goal). Nor is potential necessarily seen in descriptions of stages or processes involved in learning. It is only with end-state data that one can begin to determine the upper limits of L2 learner attainment.

The most commonly used benchmark for studying L2 learner attainment is the performance of monolingual native speakers (in section V, the limitations of this methodology are discussed). Comparisons of the outcomes of L1A and L2A allow researchers to hypothesize and test possible constraints on L2A. Similarities and differences are discerned in tasks involving auditory perception, judgments of acceptability, elicited sentence production and imitation, sentence- and word-level processing, ambiguity resolution, global-level and segmental-level pronunciation, to name some of the more frequently employed tasks. Comparisons may involve behavioral data (e.g., accuracy in acceptability judgments, degree of accent in elicited pronunciation, etc.) as well as brain-based data (e.g., electrophysiological patterns for processing syntactic and semantic anomalies; localization of brain function during sentence comprehension and production).

C. Operationalizing the End State

The construct of ultimate attainment applies locally, not globally. That is, it is not assumed that proficient L2 learners at a given point in time have effectively reached asymptote across the entire range of features of L2 linguistic knowledge, language production, and language processing. Even within a narrow domain such as constituent movement in syntax, a hypothetical learner may have reached the asymptote of attainment with respect to *wh*-movement but not with respect to verb raising.

In light of this uncertainty, selecting subjects who may be at the L2A end state involves intelligent guesswork in the form of generous residency requirements. It is not uncommon to find residence minima of 10 years or more. Because it is possible for a person to reside in the L2 context and yet be isolated from contact with the L2, the residency requirement should be accompanied by stringent criteria (or statistical controls) for L2 exposure and use.

In case studies such as Donna Lardiere's work with Patty (Lardiere, 2007), longitudinal observations in a local domain such as inflectional morphology might be expected to reveal stability of performance. Arguably, long-term stability would suggest finality of attainment in this domain. However, observable stability in production may not always be a reasonable expectation. For example, longitudinal analyses of individuals' production of overt features of morphosyntax (e.g., use of definite versus indefinite articles, past tense morphology for irregular verbs) reveal that stability in production may not ever occur (Long, 2003).[1] Indeed, even native speakers do not display unwavering stability in idiolectal performance and evaluations of acceptability (Birdsong, 2005a).

II. THE END STATE, THE INITIAL STATE, AND AGE

The concept of end state is often juxtaposed with the complementary notion of *initial state*. In L1A, the initial state is the mental apparatus, be it dedicated to language learning or to learning more generally, that the neonate brings to the task of acquiring the ambient language. For L2A, the initial state is equated with postnatal development at the cognitive, neurological, and linguistic (L1) levels.

The L2A initial state and age go hand in hand. Consider the initial state of a child who begins learning the L2 at age 3, and the initial state of an 18-year old. The initial state of the child reflects a still-developing knowledge of the L1, and relatively little cumulative use of cognitive systems for perceiving, processing, and producing the L1. Unlike this infant, the postadolescent L2 learner has in place a fully developed neurological representation of the L1 grammar, along with automatized neuromuscular routines for pronouncing the L1, and a finely tuned auditory system that enables accurate perception of L1 sounds. (Here we consider only initial-state differences in terms of development of the L1; other dimensions of initial-state differences are discussed in section III.) As this example and common sense suggest, differences in age of L2 learning imply differences in the initial state of acquisition, and vice versa.

For this reason, age of acquisition is understood to be a proxy for the initial state of L2 acquisition. Operationally, age of acquisition is a quantitative measure that represents the initial state, a complex "metavariable" (which includes prior linguistic knowledge, the state of neural and cognitive development, education, attitudes toward L2 learning, etc.) that is difficult to quantify. L2A researchers use age of acquisition in

[1] A lack of stability at the end state is one reason some researchers avoid use of the term fossilization. Critiques of the concept of fossilization are found in Birdsong (2005a), Long (2003), and MacWhinney (2005).

regressions as a predictor variable for performance at the L2A end state. In the literature, age of acquisition emerges as the strongest predictor of end-state performance of all biographical variables. “Earlier is better” is a convenient if simplistic rule of thumb that suggests this relationship.[2]

In much of the literature, “age” is shorthand for the point in a learner’s life where immersion in the L2 begins. *Age of acquisition* is frequently substituted for *age of immersion*, and is abbreviated AoA.

III. SOURCES OF AGE-RELATED EFFECTS

End-state differences between child L1A and adult L2A (and between early L2A and late L2A) are linked to AoA and are commonly chalked up to the “age factor.” However convenient and however pervasive the label, the age factor is an omnibus term that under-specifies the range of neural, cognitive, attitudinal, and experiential variables that distinguish adult L2A from child L1A. It is inappropriate to lump together, for example, neurobiological changes over increasing AoA with qualitative and quantitative changes in linguistic exposure, or with changes in attitude toward native speakers of the target language (Klein, 1995).

In the interest of conceptual granularity, when there are observed differences in ultimate attainment between early and late L2 learners, it is more accurate to speak of age-*related* effects rather than age effects. Indeed, because much of the literature explores the relationship between ultimate attainment and age of immersion, it is even more accurate to refer to *AoA*-related effects. (Because researchers do not usually split this terminological hair, the two terms will be used interchangeably in this chapter.)

The literature abounds with discussion of underlying sources of AoA-related effects in L2A. It is not possible here to summarize this literature adequately. Thorough reviews are offered by Herschensohn (2007) and Singleton and Ryan (2004). AU :2

The varied sources of age-related effects can be broken down into four major classes, which are discussed below: neurobiological, neurocognitive, cognitive-developmental, and linguistic-experiential. (Other influences on ultimate attainment are attitudinal and biographical in nature; they are considered in section VI.F.)

A. Neurobiology

Increases in neurofunctional specificity (i.e., progressive dedication of neural circuitry to a given mental operation) lead to system-level declines in plasticity. These changes over age result in difficulty in representing new linguistic knowledge. They may also speed the processing of the L1 but slow the processing of the L2. At the macro level of observation, Lenneberg (1967) cites eventual lateralization of function

[2] It is widely recognized that the potential upside of L2 learning is not reached merely by classroom study or by incidental naturalistic contact with the L2. It is also known that age of first incidental exposure and age of beginning formal study of the L2 study are at best weak predictors of ultimate attainment.

over age as an impediment to new language learning. In a similar argument, Seliger (1978) cites localization of mental function.

With respect to the cellular level, Long (1990) and Pulvermüller and Schumann (1994) identify the process of myelination as a possible impediment to postpubertal L2A. Myelin is a phospholipid contained in glial cells. Insulating axons in a sheath of myelin speeds up electrical transmission. However, this efficiency comes at a cost: synaptic plasticity is reduced in areas of the brain that are densely myelinated. During the process of myelination, glial cells also produce substances that inhibit axonal growth in neighboring neurons, reducing the likelihood of formation of new synapses. According to Pulvermüller and Schumann, the insulating and inhibiting effects of myelination may impede the establishment of new circuitry in brain areas that are associated with language learning.

de Bot (2006) suggests that the neural plasticity required for new language learning may be related to the extent and timing of synaptic pruning. As a function of language use (particularly the use of more than one language) individuals differ in the degree to which synapses are maintained or pruned.

Pinker (1994) proposes a "use it then lose it" account of the decline of language learning ability, whereby the organism is genetically programmed to dismantle the neural circuitry required for language learning once it has served its purpose, that is, once the L1 has been acquired.

B. Neurocognition

A collection of papers edited by Cabeza, Nyberg, and Park (2005) reveals the effects on cognition of age-related neurological changes, such as shrinking brain volume, hemispheric organization, functional connectivity, and declining levels of dopamine and other neurotransmitters. It is known that neurologically based declines in processing speed, cued and free recall, and working memory take place over age. A synthesis of the literature carried out by Park (2000) indicates that these declines begin at around age 20. Bialystok and Hakuta (1999) relate such life span neurocognitive changes to the ability to acquire and use an L2.

Likewise for the L2A context, Schumann et al. (2004) explore the connection between age-related declines in nigrostriatal dopamine and declines in attention, motoric sequencing, and working memory, all of which are essential to language use. Schumann et al. also implicate dopamine in motivation to learn, learning reinforcement, and suppressing L1 influence.

Ullman (2005) suggests that the neural structures subserving procedural memory (which allows for coordination of syntactic and motoric gestures in real time) are more affected by age than the neural structures responsible for declarative memory (which permits acquisition of lexical and idiosyncratic information, along with facts such as dates and lists and names). Among low-proficiency L2 users, the declarative system is a repository of memorized surface forms, whether these forms are irregular (e.g., *ran*, the past tense of *run*) or regular (e.g., *talked*, the past tense of *talk*). In low-proficient L2 use, both regular and irregular forms are retrieved from declarative memory. At high levels of L2 proficiency, however, the combinatorial aspects of language production (e.g., affixation of the regular *-ed* past tense morpheme to verb stems: *talk*+*ed*⇒ *talked*) are assumed by the procedural system, while the declarative system remains responsible for irregulars. Ullman argues that this dualistic system mirrors that of native speakers. Paradis (2004) provides a comprehensive account of the memory systems and neural structures involved in L1 and L2 use.

C. Cognitive Development

Newport (1991) proposes that postadolescents, with a large memory bandwidth, take in and try to process so much linguistic information at once that acquisition ends up incomplete. By comparison, children have a smaller short-term memory capacity; this limits them to processing fewer bits of information (i.e., fewer morphemes) at a time, with the result that acquisition becomes a tractable problem. In this sense, "less is more" in language learning.

In the Chomskyan tradition, linguists have taken varied positions on the possibility that access to Universal Grammar (UG) declines with age, with resultant nonnative-like attainment for certain abstract features of the L2. One position is that UG limits the hypothesis space of L2 learners, with the result that features of learner grammars (from initial state to end state) fall within the finite range of possibilities specified by UG (Schwartz & Sprouse, 1996; White, 2000). On another view, resetting parameters becomes increasingly difficult with age (Towell & Hawkins, 1994). A specific instantiation of this idea is the claim that L2 learners with AoA > 7 are unable to properly set parameters of certain functional categories in cases where the L1 values and the L2 values for these parameters are different (Tsimpli & Roussou, 1991). In a similar vein, Hawkins and Hattori (2006) and Tsimpli and Dimitrakopoulou (2007) claim that the ability to correctly represent L2 uninterpretable features (i.e., formal features that are devoid of strictly semantic content, such as case in English) that are not present in the L1 is lost after the closure of a critical period. However, the ability to acquire interpretable features such as [+/−past] in English is not affected. See Han (2003) and Hardin (2001) for discussion of theories of L2A initial-state UG and their relevance to the L2A end state.

Bridging UG and mainstream developmental constructs, Bley-Vroman (1989) argues that late L2 learners have no access to UG, nor to acquisition mechanisms specific to language learning; these are replaced, respectively, by knowledge of the L1 and by domain-general learning mechanisms.

D. L1 Entrenchment

With advancing AoA, there is a concomitant increase in the cumulative use of the L1 for speaking and processing. Generally speaking, as L1 representations become progressively entrenched over age, learning an L2 becomes more difficult, and the likelihood of persistent effects at the L2A end state increases.

Concerning pronunciation, Flege (1992) proposes that, with accumulated years of speaking and hearing the L1, the phonetic categories for L1 sounds become better defined. The result is that L2 vowels and consonants that are acoustically close to corresponding L1 segments are likely to assimilate into the preexisting (L1) categories. According to Flege's "unfolding hypothesis," the degree to which L2A end-state pronunciation is accented is positively correlated with the degree of development of the L1 phonetic system when L2A begins.

With respect to syntax and sentence interpretation, Brian MacWhinney's Competition Model (MacWhinney, 2005) predicts that, for example, L2 learners whose L1 canonical word order is subject-initial (Subject–Verb–Object or Subject–Object–Verb) will tend to interpret the first noun in an L2 string as the agent, even if the L2 is itself not subject-initial. MacWhinney attributes this tendency to a progressive strengthening, over increasing AoA, of the association that links noun position to noun function.

Consistent with the spirit of this proposal are results of connectionist simulations (e.g., Elman et al., 1996; Marchman, 1993) that may relate to the L2A context. As L1 representations become progressively entrenched in neural networks, rerepresentation or "unlearning" becomes progressively difficult. In other words, L2 learning is impeded with advancing AoA as a consequence of learning itself, not because of any change in the learning mechanism.

E. Discussion

A single presumed source of age effects cannot adequately account for the textured facts of end-state attainment in L2A. For example, accounts that emphasize biology over other factors and which predict zero or little incidence of nativelikeness (e.g., Hyltenstam & Abrahamsson, 2003; Johnson & Newport, 1989; Long, 1990) do not match up well with the sizable incidence of nativelike performance.

However, in light of the multifactorial nature of age effects in L2A, Birdsong (2006) suggests not discounting out of hand any empirically supported sources of age-related effects in L2A. This includes sources relating to the biology of the species, which may play out in declines in some areas of cognition (e.g., phonological working memory) and in increases in others (e.g., processing "bandwidth"). Along with this assumption of face validity, it may also be reasonably assumed that some factors and mechanisms account for more variance than others, and that the proportional effects of each of the sources on L2 processing and acquisition will vary to some extent from individual to individual (Bowden, Sanz, & Stafford, 2005; Dewaele, this volume; Dörnyei & Skehan, 2003).

IV. STUDYING AOA AND THE L2A END STATE

In L2A research, there are several possible ways of determining if there are AoA-related effects on ultimate attainment. The most frequently used procedure is regression of predictor variables onto outcome measures, or correlations that partial out covariants such as education.

Studies using regression methods normally report significant negative correlations of performance over the range of sampled AoA, hence the "earlier is better" rule of thumb. Some studies disaggregate the results into two distributions, one for early arrivals and one for late arrivals, and perform separate correlations for each distribution. This procedure produces differing slopes and correlation coefficients for each set of results.

Another approach is to compare performance of two or more participant groups (e.g., early and late arrivals). If the sample size is sufficiently large and the data are normally distributed, ANOVA or similar statistical models can be employed. In the most basic application of ANOVA in this context, the independent variable is AoA with two or more levels, and the dependent variable is quantified performance on an attainment measure.

For intergroup comparisons, learner and control groups are shown schematically below.

Learner group	*Learner group*	*Controls*
Late (postadolescent) L2	Early (preadolescent) L2	Monolingual L1
		Simultaneous L1–L2

AoA studies may involve three-way comparisons (early vs. late learners; each learner group vs. controls). One-way comparisons of late learners versus controls are also common.

In several recent studies of brain function in L2 processing (and in a few behavioral studies as well), the variable of L2 proficiency is considered along with AoA. The basic between-group designs are as follows:

Learner group	*Learner group*	*Controls*
Late (postadolescent) L2	Early (preadolescent) L2	Monolingual L1
High L2 proficiency	High L2 proficiency	Simultaneous L1–L2
Low L2 proficiency	Low L2 proficiency	

(In some cases, L1–L2 comparisons within a learner group are carried out, i.e., performance in the L2 is compared with performance in the L1 for the same subjects.)

Especially when proficiency is not controlled, it is typical to find that the performance of late L2 groups is inferior to performance of earlier-exposed groups, which are in turn inferior to performance of monolinguals and simultaneous L1–L2 bilinguals. These differences have been interpreted as indicating that the AoA-defined learner groups differ in terms of their potential for learning.

Group designs such as these set performance criteria and informatively integrate the age and proficiency variables. However, a limitation of pure between-group comparisons is that by definition they do not adequately capture the range of performance within groups. As we will see in section VI., there are individuals in late-arriving groups who perform within the range of performance of controls. Such findings are an essential complement to between-group comparisons, inasmuch as performance data from individuals contribute to our understanding of the upper limits of end-state attainment.

V. THE NATIVE SPEAKER STANDARD

Comparisons of L2 learners with monolingual native speakers are instructive. The benchmark is readily established empirically, and referencing learner performance to that of natives provides an easily understood metric of the potential for learner attainment.

The native standard is not predetermined. That is, researchers do not stipulate what is native speaker performance and what is not. In the experimental context, the native standard is considered to be the performance of a sample of a relevant population of native speakers. Natives' performance is not uniform, but is inclusive of a range of outcomes.

In L2A research, nativelikeness is often operationalized as L2 learner performance that falls within the range of performance of native controls. In other cases, the criterion for nativelikeness is performance within 1 or 2 standard deviations of the native mean.

The native standard permeates research that relates age to ultimate attainment. In the context of evidence for the CPH/L2A, for example, Long (1990) maintains that the CPH/L2A could be falsified by one L2 learner whose competence is indistinguishable from that of a native speaker. Johnson and Newport (1989) assert that biological constraints associated with maturation deterministically prevent late learners from becoming nativelike. Hyltenstam and Abrahamsson (2003) claim that it is impossible for a late learner to display nativelikeness across the complete range of language performance, and the researchers link nonnativelikeness to a loss of learning ability over age. In all three examples, the criterion is understood to be monolingual nativelikeness.

However instructive and however widespread the use of this standard, there is an inherent problem in stipulating monolingual likeness as the criterion for success in L2A. Consider the nature of bilingualism. Among bilinguals (i.e., people who routinely use both the L1 and the L2, irrespective of AoA and irrespective of proficiency in the two languages), the L1 and the L2 exert reciprocal influences on one another. Influences of the L1 on the L2 are widely recognized. Less well known are influences of the L2 on the L1, which have been observed in such varied areas as syntactic processing, judgments of acceptability for middle voice, voice onset time, and sentence-level pronunciation (see Birdsong, 2006). As Grosjean (1989) famously put it, the result of these reciprocal influences is that a bilingual is "not two monolinguals in one." Assuming that the learner is using both languages actively, the reciprocal influences in bilingualism appear to operate across all ages of immersion in the L2 (Harley & Wang, 1997).

Such observations suggest that comparisons with monolingual natives, while revealing, may not be an altogether appropriate criterion for falsifying the CPH/L2A, since the L2 of a bilingual cannot be expected to resemble, down to the most trivial detail, the language of a monolingual. In the context of AoA research more generally, what may be more illuminating than flushing out minute departures from monolingual likeness are comparisons of late and early L2 learners with bilinguals from birth. This approach has the potential for revealing how the reciprocal influences of L1 and L2 differ among the three groups.

Reciprocal effects in the two languages are a reminder that not all L1–L2 differences should be linked to the idea that language learning mechanisms deteriorate over age. A simple causal logic underscores this point. In the L1, departures from monolinguals' performance cannot possibly be the result of compromised learning of that L1; instances of nonmonolingual likeness in the L1 are reflexes of the L2 on the fully developed L1. By the same token, in the L2, at least some observed departures from monolingual standards can be attributed to processes inherent in multiple language use, rather than to declines in language-learning ability.

VI. NATIVELIKE ATTAINMENT

This section highlights behavioral and brain-based studies that reveal that some postadolescent L2 learners are capable of nativelike attainment. In most studies, nativelikeness is not tested across multiple domains. But a small number of studies summarized here do examine diverse areas of linguistic performance, and they reveal that postadolescent L2 learners are capable of attaining broad nativelikeness.

Recall that comparisons of performance of groups of native controls with groups of L2 learners almost invariably reveal intergroup differences. However, the upper limits of attainment are not established by between-group comparisons but by examining the performance of individuals.

Given that use of both the L1 and the L2 inhibits the attainment of complete monolingual nativelikeness, and given the questionable appropriateness of the monolingual standard, an exploration of nativelike attainment might appear to be unwarranted. In the discussion at the end of the section, we will consider how observed nativelike attainment might be reconciled with the nature of bilingualism.

A. Pronunciation

In the area of pronunciation, differences from native controls are found among subjects with AoAs as early as 1 or 2 years of age (Flege, 1999). A typical result is seen in Flege, Munro, and MacKay (1995). Two hundred forty Italian immigrants to Canada, with English as their L2, were asked to read aloud five short English sentences. A linear decline in accent ratings was observed over increasing AoA. The earliest AoA at which L2 learners began to fall out of the native range was age 2. Among postadolescent learners, 6 of the 120 subjects performed in the native range; all 6 had AoAs in the lower range of postadolescent subjects.

A higher rate of nativelike pronunciation is reported by Oyama (1973). On a task involving telling a personal anecdote, 6 of 36 native Italian speakers who had immigrated to the United States with AoAs at or beyond adolescence received pronunciation ratings that fell within the range of ratings received by native speakers. A still higher incidence of nativelike pronunciation emerges from the research of Bongaerts (1999). Bongaerts sampled the French pronunciation of nine Dutch-speaking subjects who were highly proficient in French. Of the nine late learners, three received ratings within the range of ratings for native controls. To obtain a more generalizable idea of the incidence of nativelikeness, Birdsong (2007) studied the pronunciation of learners who had not been screened for L2 proficiency. The sample consisted of 22 Anglophones with late AoA (≥ 18 years) residing in the Paris area.

On two subtle acoustic measures (vowel length and VOT), as well as in global-level pronunciation, 2 of the 22 subjects were indistinguishable from native controls.

B. Perception

Kuhl (2000) and Werker (1994) are among the researchers who have identified the constraining effects of the mother tongue on infants' perception of speech sounds in a new language. With exposure and training, these initial perceptual deficiencies in the L2 can be tempered or eliminated (Werker & Tees, 2005). For example, significant improvements with training have been observed with respect to Japanese speakers' difficulty perceiving the /r/-/l/ distinction in English (Bradlow, Akahane-Yamada, Pisoni, & Tohkura, 1999; McClelland, Fiez, & McCandliss, 2002). Nevertheless, the phenomenon of "listening to a second language through the ears of a first" can persist into adulthood (Cutler, 2001).

An example of nativelike perception is provided in a study by Darcy, Peperkamp, and Dupoux (2007). In English, assimilation of coronals to following labials or velars involves a shift of place of articulation. For example, if "sweet" (ending in the coronal/t/) is followed by "melon" (ending in the bilabial/m/), the resulting pronunciation is "swee[pm]elon." Similarly, "grapes" (beginning with the velar/g/) would alter the final segment of "sweet," producing "swee[kg]rapes." In contrast, with respect to obstruent clusters in French, assimilation involves the feature of voice. Thus *botte* (/b t/ = "boot") is produced as /b d/ if it is followed by an adjective beginning with a voiced obstruent, such as *grise* ("gray"). The resulting sequence is pronounced "b [dg]rise." Can native speakers of one language detect appropriately assimilated words in the other, or do they interpret the L2 as they do the L1? In Darcy et al.'s word detection task, English subjects with low French L2 proficiency mapped their L1 assimilation routine onto perception of sequences in French; the same L1-to-L2 mapping was found for French subjects who were low-proficiency learners of English. At high-proficiency levels, however, learners of both languages were able to adjust their perception of assimilation and performed like natives when listening to L2 stimuli.

C. Morphosyntax

In an influential study of French L2A, Coppieters (1987) found that no late-learning participants (who were from varied L1 backgrounds) came close to the performance of native controls in judgments of subtle syntactic contrasts in French. In the landmark study of Johnson and Newport (1989) not one of the 23 late-arriving Chinese or Korean subjects performed in the range of native controls on a test of knowledge of L2 English morphosyntax.

Birdsong (1992) carried out a partial replication of the Coppieters (1987) study and found that 15 of the 20 late-arriving Anglophone subjects performed in the range of native controls. Less impressive results were found by Birdsong and Molis (2001) in a strict replication of Johnson and Newport (1989). The 61 subjects were native speakers of Spanish. Only 1 of the 32 late arrivals scored in the native range. However, 13 late arrivals scored above 92% accuracy. Van Wuitswinkel (1994) asked Dutch speakers who had begun learning English after age 12 to judge the acceptability of a subset of the Johnson and Newport items, along with items exemplifying additional structures in English. In one group of learners, 8 of 26 participants performed like natives; in another group, 7 of 8 performed like natives.

To what can the divergent results be attributed? In the case of Birdsong (1992), there were certain procedure and materials differences from those in Coppieters (1987) that may have contributed to the divergence. In this instance, the high rate of nativelikeness could not be attributed to the fact that Birdsong's participants were Anglophones, because several of Coppieters's subjects were Anglophones and their performance, like that of the other subjects, fell outside the native range. However, we cannot exclude the possibility that the L1 of the experimental subjects influenced the rate of nativelikeness in the van Wuitswinkel (1994) and Birdsong and Molis (2001) replications of Johnson and Newport (1989). An L1 influence is also suggested by the results of Cranshaw (1997). Cranshaw examined the acquisition of tense-aspect features in English by 20 Francophone and 20 Sinophone late learners of English. While 3 of the Francophones performed like native controls, only 1 Sinophone performed like the natives.

Nativelikeness in L2 morphosyntax is not uncommon among highly proficient L2 users. For example, White and Genesee (1996) looked at the ability of Francophone late learners of English to produce and judge examples of *wh*-extraction in English. Sixteen of 45 highly proficient learners performed like natives across all tasks. In a study of the acquisition of aspectual features in Spanish, Montrul and Slabakova (2003) administered two interpretation tasks to late-learning Anglophones. Among their sample of highly proficient learners, 70% performed like natives on all sentence types in both tasks.

D. Multiple Domains

Hyltenstam and Abrahamsson (2003), Long (1990), and Scovel (2000) contend that attained nativelikeness, if observed at all, will not equal that of natives across several domains of performance. For example, an L2 user may be competent in the surface morphological features of the language, but misassign stress on polysyllabic words like ‘‘hypothesis’’ and ‘‘octopus.’’ While this is certainly the typical case, there are notable exceptions.

Marinova-Todd (2003) studied 30 highly proficient postadolescent learners of English, who had resided in the Boston area for 5 years or more. The learners and native controls performed nine tasks, which covered lexical knowledge, language use in narratives and discourse, pronunciation in spontaneous speech and read alouds, and morphosyntax in off-line and online tasks. Three of the late learners performed like native controls over all nine tasks.

Ioup, Boustagui, El Tigi, and Moselle (1994) published a case study of two Anglophones who were highly proficient late learners of Cairene Arabic. Nativelike performance was revealed in two tests involving identification of dialects of Arabic, three tasks relating to grammatical knowledge (English-to-Arabic translation, judgments of grammaticality, and interpretation of anaphora), and a free-form description task which was rated for pronunciation accuracy. With a few minor exceptions, the two subjects were indistinguishable from natives.

E. Brain-Based Studies

Examinations of brain activity reveal the degree of functional similarity between processing in the L1 and processing in the L2 (and in some cases, between early and late bilingual processing). For recent reviews, see Abutalebi, Cappa, and Perani (2005); Birdsong (2006); Stowe and Sabourin (2005).

The locus of language processing is studied with imaging techniques such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET). Electrophysiological components of language processing are investigated with event-related brain potential (ERP) methodologies, a variant of electroencephalography. The timing of language processing events, such as reactions to semantic and syntactic anomalies, is revealed by measurements of brain activity through the scalp.

Brain-related research in L2A has focused on AoA and L2 proficiency as predictors of degree of similarity. Production studies using fMRI reveal that high-proficiency learners, even those with late AoA, tend to resemble monolingual natives in terms of regional brain activity during such tasks as word repetition, cued word generation, and sentence generation (see Birdsong, 2006). In a PET study involving listening to a story, Perani et al. (1998) compared the brain activity of late and early bilinguals (there was no comparison with monolinguals in this study). Subjects in both groups were highly proficient in the L2. The researchers found overlapping patterns of brain activity for the early and late bilinguals.

In general, the ERP literature suggests that, for high-proficient L2 users, reactions to syntactic anomalies (the P600 effect) and to semantic anomalies (the N400 effect) take place at the same poststimulus latencies as L1 users. Overlooking many details, this generalization extends to late-arriving learners (see Birdsong, 2006)

The relevance of proficiency is demonstrated in a study done by Sabourin (2003). Subjects were only fairly proficient late learners of Dutch and were native speakers of German, English, or a Romance language. All three groups performed slightly below natives on grammaticality judgments relating to verb agreement. However, on ERP readings taken concurrently with the behavioral task, none of three groups were identical to Dutch controls (although the German natives showed roughly nativelike N400 and P600 responses).

An emerging pattern in both imaging work (which relates to the ‘‘where’’ of language processing) and electrophysiological work (which relates to the ‘‘when’’ of processing) is that L2 proficiency is a more robust and reliable predictor of functional similarity than AoA. By and large, brain-based data reveal that processing in the L1 and processing in the L2 begin to converge with increasing L2 proficiency (Green, Crinion, & Price, 2006). Exceptions to this tendency are discussed in Clahsen and Felser (2006); see also section VI.F.

F. Discussion

Given the nature of bilingualism (see section V), how can we explain attained nativelikeness? There are two main approaches to reconciling nativelikeness with L1 effects in bilingualism.

One approach is to suggest that nativelikeness is observed because the tasks subjects perform are not sufficiently challenging. For example, off-line tasks such read alouds and unpaced judgments of grammaticality may not put a sufficiently heavy cognitive load on subjects to reveal learner-native differences. This argument is not consistent, however, with results of online tasks in Juffs and Harrington (1995) and Marinova-Todd (2003). Relatedly, it may be that the experimental tasks employed do not tap subtleties in grammatical knowledge. This possibility is countered by results of Birdsong (1992) and Ioup et al. (1994).

However, the argument that nativelikeness is restricted to certain types of processing and linguistic knowledge finds support in research by Clahsen and Felser (2006) and Sorace (2003). The results of experiments reported by Clahsen and Felser suggest that, in sentence parsing, both monolinguals and highly proficient late L2 learners use lexical and semantic cues for interpretation. However, compared to natives, learners tend to rely less on syntactic information. Both behavioral and brain-based evidence suggests that L1 processing involves detailed structural representations, whereas L2 processing is comparatively shallow. Consistent with the idea that L2–L1 differences are revealed in processing tasks are results from studies of lexical retrieval, structural ambiguity resolution, and detection of acoustic features of speech (see Birdsong, 2006). Sorace's research focuses on the interface between semantics and syntax. Languages like Italian do not require overt subjects when there is no shift of topic in the discourse; conversely, overt subjects are required when there is a shift of topic. English, however, requires subjects whether there is a shift of topic or not. Sorace proposes that English L1 learners of Italian L2 do not recognize the abstract relationship between topic and occurrence of overt subjects. Rather, they consider the realization of overt subjects to be optional in Italian, and not governed by the Italian rule that specifies the conditions under which subjects are required.

Another approach to reconciling nativelikeness with obstacles to learning involves the possibility that nativelike attainers distinguish themselves in terms of a cluster of attributes that favor high levels of attainment. For example, nativelikeness may not be possible without motivation to learn and to assimilate psycho-socially into the L2 linguistic culture (Klein, 1995). Education is another learner variable that affects L2A outcomes. For example, education in the L2 environment predicts attainment of regular features of inflectional morphology (Flege, Yeni-Komshian, & Liu, 1999). Along the same lines, amount of L2 use is predictive of degree of nativelikeness in L2 pronunciation (Flege & Liu, 2001). Especially in the area of pronunciation, phonetic training (formal or informal) may be a *sine qua non* for attainment of nativelikeness (Birdsong, 2007; Bongaerts, 1999).

The distinction between necessary and sufficient conditions applies here. Strengths in these affective and experiential dimensions are not sufficient in themselves to guarantee high levels of attainment or nativelikeness. At the same time, in the absence of such strengths, nativelikeness is unlikely.

A more complex picture emerges from studies of aptitude and L2A ultimate attainment. Aptitude in language learning (which typically takes place in structured classroom environments) is predictive of ease of certain types of L2 learning (Robinson, 2001). However, the literature on the relation of foreign-language aptitude to ultimate L2 attainment is mixed.

DeKeyser (2000) administered a test of English morphosyntactic knowledge to L1 Hungarian subjects at the end state of English L2A. Among the late AoA subjects, three of the four best performers had received high scores on a test of foreign language-learning aptitude/talent. However, many of the high-aptitude subjects in the DeKeyser study did not score well on the measure of morphosyntactic knowledge. The finding that one of the best performers did not have high aptitude raises further questions about the predictive value of this trait.

Schneiderman (1991) compared the foreign-language learning aptitudes of a group of near-nativelike attainers and a group of learners with somewhat lower attainment. Across a battery of measures, both groups showed modest aptitude levels, suggesting that the association between aptitude and outcome is weak. The evidence further suggests that freakishly high levels of aptitude may not be a *sine qua non* for high attainment in L2A.

It is likely that more granular approaches will better establish the connection between aptitude and proficiency at the end state. For example, Winke (2005) found that, of the various components of the Defense Language Aptitude Battery, only phonological working memory was predictive of advanced attainment.

One additional learner attribute to considered in the context of nativelike attainment is L2 dominance. For some L2 learners, including late L2 learners, the second language learned is more often spoken (and heard, read, and written) than the first. Relative frequency of use is one dimension of dominance. Another dimension of dominance is psycholinguistic in nature. Psycholinguistically, language dominance is operationalized in such tasks as speeded picture and number naming, and recall of words heard under noise. The L2 is considered dominant if it is processed with greater accuracy and speed than the L1.

By either definition, dominance is a matter of degree. That is, L2-dominants differ quantitatively in their relative use of the L2 and in their performance on the psycholinguistic tasks.

A proficient L2 learner is not necessarily L2-dominant. A study by Flege, MacKay, and Piske (2002) suggests that the distinction between proficiency and dominance may play out in observed nativelikeness. Their study involved three groups of Italian L1/English L2 bilinguals: one group was English (L2) dominant, one was Italian dominant, and a third group was composed of individuals who were highly proficient in both languages. While the latter two groups had detectable accents, the L2-dominants were indistinguishable from natives. The authors speculate that effects of the L1 diminish with increased L2 dominance.

What if contact with the L1 were eliminated altogether? The findings of a study by Pallier et al. (2003) are suggestive in this regard. Subjects were eight Korean adoptees who were brought to Paris at ages ranging from 3 to 8 years. On informal behavioral measures as well as on experimental tasks tapping implicit knowledge of French (Ventureyra, 2005), the adoptees were indistinguishable from monolingual French natives. The same was true for regional brain activity while listening to French, as revealed by fMRI. Behavioral as well as brain-based evidence revealed no trace of knowledge of Korean: the adoptees appeared to have completely "forgotten" their L1. Under conditions of extreme L1 loss, the neural substrates for language learning appear plastic enough to acquire an L2 to monolingual-like levels.

To summarize, high levels of motivation, linguistic training, and education in the L2 milieu are likely to characterize individuals who attain a high level of nativelikeness in the L2. However, these traits alone cannot be expected to suppress L1 effects in the L2. The key to overcoming bilingualism effects may reside in L2 use and L2 dominance. L1 effects are mitigated if the L1 is infrequently used. The intrusion of the L1 is perhaps more minimized if the L2 is dominant in terms of processing and use, even more so if the L1 is not used at all.

Thus we can speculate with some degree of confidence that nativelikeness is not out of the question for individuals with high levels of motivation, education, L2 use, and L2 dominance, and (possibly) foreign-language learning aptitude. However, further testing along the lines of Clahsen and Felser (2006) and Sorace (2003) will determine the empirical adequacy of this speculation.

VII. THE AOA FUNCTION

A. Is There a Critical Period for L2A?

The function that relates AoA to end-state attainment has been interpreted as evidence for and against a critical period in L2A. The AoA function is the best-fitting line through points in a distribution of L2 learner performance (e.g., grammatical accuracy, accentedness, etc.). Observable declines in the function reveal the effects of AoA, or, more precisely, the effects of factors that covary with AoA.

The most commonly observed AoA function is a straight line that begins at early childhood and continues over the AoA span. Since in this instance AoA effects are not confined to a circumscribed temporal span (i.e., a period), a straight-line function is not compatible with the notion of a critical period. However, it is consistent with the literature on neurological and cognitive aging (Birdsong, 2006).

Three AoA functions that contain a period are presented in crude and idealized form here. On one view, declines in end-state attainment begin at a very early AoA and then level off. After the point of articulation that marks the start of the leveling, there are no further performance declines over AoA. The resulting geometry resembles a stretched "L" which is represented by the image in Figure 1A. AU :4

On another view, the function is flat and performance is at ceiling in preadolescent AoA, after which begin declines in end-state attainment. The AoA function roughly resembles a stretched "7" and is represented in Figure 1B. On the left, a flat segment

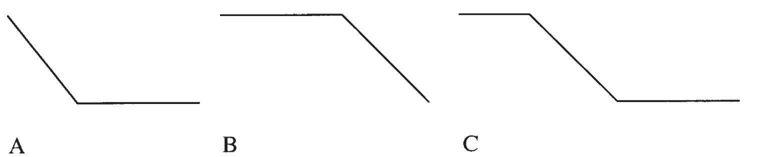

Figure 1 Three patterns of bounded age effects. (A) Stretched "L" shape; (B) stretched "7" shape; and (C) stretched "Z" shape. *Note*: To simplify visualization, the vertical axis (representing performance, or level of end-state attainment) and the horizontal axis (representing AoA) have been removed from all three figures.

signifies a null effect for AoA. The absence of a performance decrement in this segment corresponds to the idea of a circumscribed window of opportunity for nativelike attainment. On the right end of the function, the AoA effects persist indefinitely.

A third version is a hybrid of the first two, and is shown in Figure 1C. This stretched "Z"-shaped figure is composed of a finite window of opportunity, the onset and end of a decline, and a leveling off of the function. As in Figure 1A, after the rightmost articulation in the AoA function, there is no further performance decline over increasing AoA.

Note that in Figure 1A, the decline with increasing AoA is confined to a period. In Figure 1B, it is the lack of decline with increasing AoA that is confined to a period. Figure 1C incorporates two periods. The first is a finite null effect for AoA, followed by a finite AoA effect.

Thus, a common feature of each of these figures is at least one finite span, conforming to a strict interpretation of a "period" that is deemed optimal or critical for L2 mastery. (The same logic can apply to the term *sensitive period*, which is often associated with a function whose declines are less steep and their timing more variable than those of a critical period. In the present contribution, *critical period* will be used as a cover term for both phenomena. For further discussion, see Knudsen, 2004.)

B. Are Critical Period Effects Maturational in Nature? (1)

The schematic figures given here represent critical periods in the AoA function. These periods can be interpreted as reflecting maturational influences if their span coincides with biologically specified maturational epochs in development. That is to say, maturational effects would be suggested if the points of articulation coincide with the end of maturation. Thus, in the functions represented by Figure 1A and C, a case for maturational effects could be made if the span of age-related decline terminates around the end of maturation. For the function in Figure 1B, maturational effects would be suggested if the decline begins around the end of maturation; that is, if the closure of the window of opportunity coincides with the end of maturation.

Note that the end of maturation coincides, on the one hand, with the beginning of age-related declines (Figure 1B), and on the other hand, with the end of age-related declines (Figure 1A and C). The literature is unclear about whether the role of maturation is to delay declines or end declines, or both. This is a fundamental conceptual and theoretical issue that awaits a principled resolution.

C. Are Critical Period Effects Maturational in Nature? (2)

Let us now consider functions whose points of articulation do not line up with the end of maturation. Suppose the flat segments on the left of the functions in Figure 1A and C terminate at a point prior to the end of maturation, for example, at an AoA of 7 years as observed by Johnson and Newport (1989). How can one explain the onset of the decline that does not match up with the end of maturation? One possible explanation is that the timing of the decline is unrelated to maturation. For example, the onset of declines might reflect a threshold after which the effects of L1 entrenchment begin to cascade. It could also be that individuals who begin learning at age 7 immerse themselves less in the L2 than their earlier-AoA counterparts. An AoA of 7 might coincide with a decline in motivation to learn the L2 or to assimilate with native speakers of the L2.

However, maturational explanations cannot be ruled out. It is possible that biological mechanisms contributing to attainment declines assert themselves at ages prior to the end of maturation. In other words, on this view not all maturational effects have to be keyed to the point at which (neuro)biological maturation ceases. Thus, for example, Scovel (1988) posits a brief window of opportunity for nativelike pronunciation relative to nativelike morphosyntax, owing to the early onset of declines in the neuromuscular coordination of articulators in the vocal apparatus.

Along these lines, Moyer (1999) and Singleton and Ryan (2004) point out that the observed duration of the window of opportunity is likely to depend on what domain of linguistic attainment is being tested. Observed differences in the timing of declines support the notion of "multiple critical periods" for different components of linguistic knowledge and processing (Seliger, 1978).

The same type of argument can be applied to the onset of declines in the L-shaped and Z-shaped functions. Some factor(s) other than biological aging (e.g., the onset of L1 effects) could trigger the declines. The effects may run their course and stop at a point prior to adolescence, after which no further declines would be expected. However, as with prematurational declines in the seven-shaped figure, biology cannot be ruled out. Some unspecified biological factor may exert its influence prior to the end of maturation, and not thereafter. No biological explanation suggests itself, however, if the point of articulation in the L-shaped figure appears after the end of maturation.

Clearly, if a case is to be made for any of these possibilities, it is necessary to identify the nature of the presumed sources of the effects and to specify their relationship to timing parameters of the AoA function.

D. Approaches to Analysis (1)

Birdsong (2005b) reviews the published L2 behavioral evidence relating to the three functions presented above. Analyses of pooled data (performance of learners across the full span of AoA) are to be distinguished from analyses of disaggregated data, where separate analyses are performed on early-arriving and late-arriving subjects.

With respect to pooled data, all studies reveal declines in ultimate attainment persisting beyond the end of maturation. The AoA function that best fits the pooled data is roughly a straight line, with no distinct prematurational window of opportunity feature or postmaturational leveling off feature. (It should be noted the number of data points is usually low, and the data have typically not been subjected to nonlinear modeling.)

A slightly more mixed picture emerges when data from early and late arrivals are disaggregated. For early learners, there is some evidence of declines of ultimate attainment. These results are thus roughly consistent with Figure 1A and with the middle segment of Figure 1C, with the exception that, in these studies, the end of maturation does not mark the beginning of an orderly leveling off of the function, but rather a random dispersion of performance.

For late learners, several studies reviewed reveal ultimate attainment declines that persist beyond the end of maturation. Though the onset of declines varies, such results nevertheless reveal an ongoing decline in ultimate attainment over increasing AoA (see Figure 1B).

In the context of disaggregated analyses, two sets of data are worthy of note. Johnson and Newport (1989) relate their results to the notion that declines in ultimate attainment level cease around AoA = 16. Their results unambiguously indicate a decline in ultimate attainment up to AoA of about 16 years. They argue that this decline is followed by a leveling off and no further decline (Figure 1A and C). This would be in line with their view that age effects should cease at the end of maturation (see also Pinker, 1994; Pulvermüller & Schumann, 1994). While the decline over AoA is uncontroversial, the leveling-off feature, so crucial to this particular maturational account, has been called into question. Bialystok and Hakuta's (1994) reanalysis indicates that the declines actually persist past the end of maturation. Birdsong's (2005b) analysis of the late-arrivals' results reveals no orderly flattening of the function, but random performance. With respect to the window of opportunity geometry (Figure 1B), Birdsong and Molis (2001), using the same materials and procedures as Johnson and Newport (1989), found a flat segment at the top of the function (i.e., a ceiling effect) among their early-arriving subjects that persisted until an AoA of 27.5 years. Because the span of null AoA effects extends well into adulthood, the period cannot be construed as maturational in nature.

E. Approaches to Analysis (2)

A minimal criterion for maturational effects is an articulation in the AoA function, a point where the slope of the function changes. The reasoning here is that a significant departure from linearity would suggest the onset of a qualitative change in learning ability. (Note that a departure from linearity might also be consistent with other age-related phenomena. For example, as mentioned above, it might signal a threshold after which L1 entrenchment effects are manifest in ultimate attainment.)

With respect to pooled data, there is little decisive evidence of nonlinearity or discontinuity that would suggest the onset of a decline in learning ability. This said, there is considerable controversy regarding the appropriate statistical and sampling measures for demonstrating departures from linearity. Also considered are the separation of length of residence, chronological age, and AoA effects; the timing along the AoA function of any putative elbow; and the possibility that an elbow might exist for attainment of L2 morphosyntax but not for pronunciation (Flege et al., 1999; Hakuta, Bialystok, & Wiley, 2003: Stevens, 2006).

It should be noted that nonlinear models applied to large numbers of data points are more revealing than simple regressions applied to the small data sets that are common in L2A research. Note too that the disaggregation procedure invariably produces departures from linearity. This is so because, in any distribution that does not yield a correlation equal to exactly +1 or −1, two separate functions account for more variance than a single function. Minor slope differences between two linear functions (imagine a slight bend in a drinking straw) can be simple artifacts of disaggregation, and thus may not represent a qualitative change in language learning.

VIII. CONCLUSION

In this contribution, a central concern was the impact of age-related factors on end-state attainment in L2A. We considered this question from diverse methodological, analytic, and theoretical perspectives. The topics addressed include the monolingual standard, the attainment of nativelikeness in the face of obstacles to learning, and the adequacy of maturational accounts of age effects.

Another recurrent theme in this chapter is the upper limits of attainment among late L2 learners. The past 15 years have witnessed an expansion of research that investigates learner potential. The goal of these efforts goes beyond inventorying what late L2 learners are capable of doing. Rather, the goal is to produce an unbiased, composite picture of late learner attainment, a picture that integrates models of acquisition, external constraining and enabling factors, learner variables, facts of neurocognition over the life span, and features of processing and knowledge at the end state. It is in these rich and varied dimensions that the upper limits of attainment are explored.

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