Introduction

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This volume is a harvest of articles from the first conference in a series on the cognitive neuroscience of language. The first conference focused on the cognitive neuroscience of second language acquisition (henceforth SLA). It brought together experts from as diverse fields as second language acquisition, bilingualism, cognitive neuroscience, and neuroanatomy. The articles and discussion articles presented here illustrate state-of-the-art findings and represent a wide range of theoretical approaches to classic as well as newer SLA issues. The theoretical themes cover age effects in SLA related to the so-called Critical Period Hypothesis and issues of ultimate attainment and focus both on age effects pertaining to childhood and to aging. Other familiar SLA topics are the effects of proficiency and learning as well as issues concerning the difference between the end product and the process that yields that product, here discussed in terms of convergence and degeneracy. A topic more related to actual usage of a second language once acquired concerns how multilingual speakers control and regulate their two languages.

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Age Effects

The first important issue concerns the nature and origin of age effects in SLA. Although it is uncontroversial that SLA becomes, on average, less successful with increasing age of acquisition, why this is the case is much debated. A frequently held assumption is that of a *critical period* for language acquisition, after which SLA becomes fundamentally different in one way or another.

The notion of a critical period is borrowed from biology and refers to the phenomenon that certain abilities, such as stereoscopic vision or a particular type of birdsong, might only be acquired if appropriate external stimulation is provided during a certain time window in the ontogenetic development of the individual. If this time window is missed, acquisition of the ability in question becomes impossible or at least imperfect (in the latter case, one speaks of a *sensitive* period; see Knudsen, 2004). Although it is not clear exactly how the animal brain responds to the external stimulation by developing the neural structures subserving a particular skill, it seems clear that at the end of a critical period, there must be some change in the brain that stops its responsiveness.

Researchers who assume that an analogous brain-based mechanism underlies language acquisition in humans tend to view the imperfect attainment of a second language following late exposure as an indication that the mechanism has ceased to function. Of course, not all brain changes have the temporal (and functional) properties of critical periods. Age effects might also be due to changes of brain structure and function over the lifetime that are not specific to language acquisition but that, nevertheless, affect it. David Birdsong critically discusses different versions of the critical period hypothesis and provides an overview of general and regional age-related brain changes as well as cognitive changes that might account for age effects in SLA without assuming a critical period. Harry Uylings discusses the notion of a critical period from the perspective of the neuroanatomist and

distinguishes different types of critical periods. He provides in-depth information about neuroanatomical prenatal and postnatal changes in the development of the cortex. Peter Hagoort argues that structural neuroanatomy as such provides fewer insights into language acquisition and processing than the investigation of functional brain activation patterns.

Age effects have not only been observed for performance in a second language but also in the brain activation patterns during second language processing. Peter Indefrey presents a meta-analysis of hemodynamic studies that examined within-subject differences between the first language (L1) and a second language (L2). He finds that L2 onset seems to play a role in activation differences related to syntactic/sentence processing, but less so for other processing levels. Jutta Mueller presents event-related potential (ERP) studies investigating age effects in a task that was designed to achieve comparable proficiency in L1 and L2 participants using a miniature version of Japanese. She concludes that the observed differences in electrophysiological responses to grammatical violations might be interpreted as supporting the notion of a critical period. Monique Lamers cautions against equating performance on a small subset of Japanese and proficiency. If proficiency is understood in the broader sense of everything that the participants know about Japanese, the two subject groups are no longer comparable in this respect and the age-of-acquisition variable might be a disguised competence variable.

Proficiency

The second important variable influencing L2 performance is proficiency. More recently, proficiency has also been linked to functional (Chee, Soon, Lee, & Pallier, 2004) and structural (Mechelli et al., 2004) brain changes. It is important to note, however, that not all designs allow for a distinction between changes that occur as a consequence of becoming proficient in a second language and preexisting anatomical or functional neural differences that might cause some individuals to acquire languages

better than others. It is also problematic that, at least in the language domain, we lack a real understanding of the functional significance of differences at the neural level. Observed differences tend to be interpreted in a circular manner starting from the (plausible) assumption that whatever is found in the more proficient speakers must be more effective, be it an increase or decrease of hemodynamic activation, an increase or decrease of gray matter. In a second step, more or less convincing speculations as to why it might be more effective are added. The chapters by Indefrey and Laurie Stowe both contribute to this type of speculation, but they attempt to narrow the interpretation space by searching for commonalities across studies.

Proficiency is mostly correlated with age of acquisition (AoA). Therefore, its effect can only be assessed if the effect of AoA is in some way controlled. One way to achieve such control is to study L2 learners with a common starting point (typically zero L2 knowledge) longitudinally while they are learning a new language. Indefrey and Lee Osterhout and colleagues report data from hemodynamic and electrophysiological studies using this approach. Osterhout et al. are particularly interested in what it means to become proficient and suggest a possible operationalization of proficiency in terms of online processing ability. Doug Davidson points out that even in groups of learners with a common starting point, individual differences might have substantial effects and suggests methodological approaches to this problem.

Convergence

The term *convergence* refers to a process whereby the representations of two languages become more similar either as a function of increasing proficiency or time—for instance, duration of L2 learning (cf. Bullock & Toribio, 2004; Clyne, 2003). However, the term is used in a number of different ways as applied to different situations and phenomena. Some authors might use this term in reference to a processing level, whereas others use it when referring to the neural level. To make things worse, the term

might also be used to describe the relationship between the first and second language within an individual speaker or to describe a situation between speakers in contact where a given language is one speaker's L1 and another speaker's L2. Obviously, this could easily lead to confusion, especially because the term might be used to describe opposite findings at the neural level. Mueller, for example, uses the term to describe her finding that a specific neural response (the so-called P600) is similar for L1 and L2 processing in proficient L2 speakers. By contrast, David Green and colleagues discuss a concept of convergence that assumes that over time, the processing and the neural representation of a L2 in L2 speakers will become similar to the representation of this language in L1 speakers due to the processing requirements of the language itself. As a consequence, the neural correlates of the L1 and L2 within a bilingual speaker should become different. Indefrey's meta-analysis of hemodynamic studies comparing L1 and L2 within subjects speaks directly to the latter prediction, but finds no evidence for it. Stowe warns that a failure to observe reliable L1/L2 differences might at least in part be due to a lack of statistical power and individual anatomical differences.

According to Green et al., convergence to a new language also underlies structural brain differences found in L2 speakers (Mechelli et al., 2004). Kees de Bot points out that it is not clear whether structural or functional differences at the neural level are a consequence of L2 acquisition or are in fact preexisting differences that might have influenced L2 acquisition.

Degeneracy

A crucial matter for research on L2 acquisition is the relationship between the observed behavior and the underlying processes. David Birdsong and Peter Coopmans both warn against the common assumption that the product necessarily reflects the underlying process in a straightforward manner. In other words, it might not be warranted to infer that differences in performance in L1/L2 processing imply different underlying processes

or, conversely, that similarities in performance imply similar processes. The latter consideration is lately more and more referred to with the term *degeneracy*, thoroughly discussed by Green et al. Note that when taking the neural level into account, degeneracy can refer to two different situations that should be distinguished: (a) The same behavior/performance/goal can be achieved by different underlying processes (which, in turn, have different neural correlates); (b) the same behavior/performance/goal can be achieved by the *same* underlying processes, which, however, might have different neural correlates because more than one brain system is capable of subserving this process. Mueller provides a nice example of a degeneracy (type a) explanation when suggesting that her L2 speakers perform at the same level as L1 speakers in grammaticality judgments but use a different, prosody-based mechanism to do so.

Control

Whereas the previous issues consider the two languages of a bilingual speaker separately, the issue of control concerns the interaction of the two languages. What needs to be explained is how the bilingual speaker manages to speak or comprehend one language at a time without more than the occasional interference of the other language. Our understanding of this ability is still very limited and the full range of possible mechanisms suggested by common sense has been proposed. These range from the assumption that the two languages have separate lexicons that do not interact to full lexical integration. The more the representations of the two languages are integrated, the more additional mechanisms are needed to regulate the appropriate language output in a given communicative situation. Suggested control mechanisms might increase the activation level of the target language, inhibit the other language, or affect the selection of L1 or L2 lexical items based on a high-level goal representation.

Antoni Rodriguez-Fornells and colleagues discuss executive/cognitive control and regulation of language choice in production (both in the sense of interference suppression and

response inhibition), favoring a language-neutral view of the mechanism. They review models of control for speech production and propose a model for control inhibition that combines a top-down regulatory function associated with the prefrontal cortex and a more local bottom-up mechanism regulating the activation level of the nontarget language. Ton Dijkstra and Walter van Heuven point out that there is massive evidence for language nonselective lexical access and that different kinds of cognitive control are at work and should be distinguished (e.g., monitoring and conflict resolution). They argue strongly in favor of an integrative approach combining neurocognitive studies with behavioral studies and computational modeling to provide theoretical coherence. Green et al. also suggest a network of control, corresponding to different levels of control (goal maintenance, management of competing tasks), language selection, and response selection. Birdsong sees working memory as the crucial control instance and emphasizes its executive role in the suppression of irrelevant information. He suggests that age effects on these components in L2 use are likely to be more pronounced than in the L1 case, due to a relatively low degree of *automaticity* in L2 processing.

Concluding Remarks

The articles in this volume chart the current state of the art in a rapidly growing field of study, touching on a range of theoretical questions. They also outline new venues of research in a new approach to understanding language, the acquisition of language in adults, and the usage of several languages in the minds and brains of multilingual speakers. We hope that the articles in this volume will convey some of the excitement and sense of momentum from the conference to a broader audience.

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