# Introduction*

The papers in this Special Issue focus on the use of neuroimaging techniques to answer questions about the neural representation, processing and control of two languages. Neuropsychological data from bilingual aphasics remain vital if we are to establish the neural basis of language (see Paradis, 1995) but lesion-deficit studies alone cannot tell us how neural activity relates to ongoing language processing. Modern neuroimaging methods provide a means to do so. There are two broad classes of such methods: electrophysiological methods allow us to answer questions about when a particular process occurs whereas haemodynamic methods allow us to answer the complementary question of where in the brain such a process is carried out. Before giving a thumbnail sketch of the papers in this Special Issue, I briefly discuss each class of method.

Electrophysiological methods measure neural activity directly for a population of neurons oriented in roughly the same direction and not too distant from the scalp. Such neurons can act like dipoles when they are polarized or depolarized synchronously. Their individual reactions summate to create a field detectable outside the head. An EEG or electroencephologram captures the electrical component of this field. (The magnetic component is captured in a magnetoencephologram, MEG.) Typically, a cognitive process is examined using event-related potentials (ERPs). These are derived by averaging signals from the EEG over a series of trials that are time-locked to the presentation of a particular type of word or stimulus. An ERP itself comprises various components (i.e., positive and negative voltage peaks). Where these are altered in their amplitude or timing by some experimental factor they are termed ERP effects. One problem with the method is that it is difficult to localize the generator or generators of an ERP effect. Indeed, without further constraints it is impossible to determine the generator of an effect since the same effect is compatible with an infinite number of different neural generators (the "inverse problem" – see Kutas, Federmeier and Sereno, 2000, for recent innovations aimed at addressing this problem).

Haemodynamic methods (positron emission tomography, PET; or functional magnetic resonance imaging, fMRI) rely on a close coupling between changes in the activation of a population of neurons and change in blood supply. A haemodynamic effect arises only when there is a change in the overall metabolic demand in a neuronal population. The two haemodynamic methods considered in this issue (PET; fMRI) track different signals. PET measures the decay of a short-lived isotope which accumulates in a neural region in proportion to the amount of blood flowing through that region. The most typical fMRI method indexes metabolic demand and hence relative neural activity by assessing the ratio of deoxy- to oxyhaemoglobin in the blood. Each method has advantages and disadvantages. Minimally, PET studies examine changes in patterns of activation by contrasting conditions that differ in the cognitive operation of interest. Trials of a certain type have to be blocked and the number of observations is restricted because PET involves the administration of ionizing radiation. There are no such constraints in the case of fMRI. However, PET has the advantage that it is more or less equally sensitive to activity in all brain regions whereas fMRI signals are not. The magnetic signal is susceptible to factors other than blood oxygenation levels making it difficult to record from certain regions (e.g., the orbitofrontal region). With these methodological cautions in mind (see Rugg, 2000 for an extensive treatment), a few words about the content of the papers in this Special Issue.

Any attempt to understand the neural basis of language processes using neuroimaging methods must be guided by a theory or model and an understanding of the tasks that we ask participants to perform. Models and theories differ in scope. Some are at the large scale and others at the scale of specific issues and concerns. Ullman's paper describes a model at the large scale and references in support of it the full panoply of behavioural, lesion, ERP and functional imaging studies. Ullman argues that the lexicon is stored in a neural system that subserves

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declarative memory in general. In contrast, grammar is mediated by a procedural system that subserves motor skills in general. In contrast to a first language, the declarative system represents both the lexical and the grammatical aspects of a second language, at least initially. This is a bold conjecture and regardless of its ultimate truth suggests a range of interesting studies including ones on the bases of individual differences in second language acquisition and attainment (see Kroll, Michael, Tokowicz and Dufour, 2001 for an interesting behavioural study of acquisition)

Hahne and Friederici examine ERP effects in response to phrase structure violations and semantic anomaly to argue for qualitative differences between native speakers and late learners of a language in their sentence processing. Learners, they suggest, identify lexical content independently of morphological form (e.g., the past participle form of the verb) and construct a representation directly based on conceptual information. An important further question is whether or not the differing ERP processing profiles of native speakers and second-language learners converge as second-language proficiency increases. Kotz uses a priming technique to assess the generality of the claim (see the revised hierarchical model, Kroll and Stewart, 1994) that lexical representations in L1 are more closely connected to conceptual representations than those in L2. At least for these speakers, priming is shown to be equivalent for the two languages and there is no quantitative or qualitative difference in the ERP effect. De Bruijn, Dijkstra, Chwilla and Schriefers address the related question of the extent to which lexical access in visual word recognition is biased by the immediate linguistic context (here a single word). Reaction time and ERP data show convincingly that it is not. Specifically, both the English and Dutch meanings of an interlingual homograph such as ANGEL appear to be equally activated whether the local context contains a Dutch word or not. Does lexical access during sentence processing in bilinguals operate in the same way? Presumably so, if we judge by work on the resolution of lexical ambiguity within a single language.

In production, the names of an object in both languages may also be accessed especially when individuals are required to switch repeatedly between languages. Guided by haemodynamic and lesion data, Jackson, Swainson, Cunnington and Jackson report two associated ERP effects when individuals are required to switch languages in naming visually presented numerals. One effect has a frontal distribution and the other a parietal distribution. Most interestingly they find that the frontal ERP component has the same distribution as that obtained in a Go/No Go reaction time task. Such an outcome supports the view that language switching involves an inhibitory process. Indeed modulation of the frontal component is greater when individuals are required to switch into their less dominant language consistent with the idea that it is more difficult to suppress a naming response in the dominant language.

The final two papers focus on haemodynamic data. Abutalabi, Cappa and Perani present a clear and succinct overview of their own and others' research on comprehension and production in bilinguals. On the basis of available evidence, they conclude that activation patterns observed during second-language processing converge on those observed during first-language processing as proficiency in the second language increases. However, current studies are either single-word studies or involve discourse level processes as well. We lack studies that selectively examine grammatical processing or encoding. Ideally, we need ERP and haemodynamic studies that use the same materials so that we can index both when and where grammatical operations, for example, are carried out. Green and Price consider how to extend haemodynamic methods to the study of recovery patterns in bilingual aphasics. They argue for the need for explicit theory and a clear understanding of task, and identify a number of methodological requirements if haemodynamic methods are to be used to amplify our understanding of recovery patterns in bilingual aphasics. Central to their paper is the contrast between the neural representation of languages and their control. They use this contrast to propose haemodynamic studies of different patterns of recovery and express the hope that a causal understanding of recovery patterns will lead to the design of effective programmes of rehabilitation.

We are at the beginning of a research programme to construct a cognitive neuroscience of bilingualism. Of course, the range of languages studied remains restricted and the range of tasks explored remains limited but hopefully this Special Issue shows that the goal is worth striving for and that there are exciting times ahead.

## References

Kroll, J. F. & Stewart, E. (1994). Category interference in translation and picture naming: evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, 33, 149–174.

Kroll, J. F., Michael, E., Tokowicz, N., & Dufour, R. (2001). The development of lexical fluency in a second

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language. Manuscript (submitted for publication), Psychology department, Penn State University.
Kutas, M., Federmeier, K. D. & Sereno, M. I. (2000). Current approaches to mapping language in electromagnetic space. In C. Brown & P. Hagoort (eds.), *The neurocognition of language*, pp. 359–392. Oxford: Oxford University Press.
Paradis, M. (1995). Epilogue. In M. Paradis (ed.) *Aspects of bilingual aphasia*, pp. 211–223. New York: Pergamon/Elsevier Science.
Rugg, M. R. (2000). Functional neuroimaging in cognitive science. In C. Brown & P. Hagoort (eds.), *The neurocognition of language*, pp. 15–36. Oxford: Oxford University Press.

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