NEUROLINGUISTIC PERSPECTIVES ON MOTHER TONGUE: EVIDENCE FROM APHASIA AND BRAIN IMAGING

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Neurolinguists are interested in how language is organized and processed in the brain. With respect to the mother tongue, we ask the following question: how is the mother tongue organized relative to other languages in the brain? In order to begin to answer this question, we must look at what is known about language organization in the brain and how such information is gathered by neurolinguists. To set the stage for our discussion of bilingualism, we will begin with a discussion of aphasia (the language deficit resulting from damage to the language centers of the brain). We will then explain how research on polyglot aphasics has advanced our knowledge of the representation of language and languages in normal brains, particularly with respect to the mother tongue. We will integrate the pertinent literature from aphasia research and from more direct observations of language processing such as cortical stimulation and other forms of brain imaging. We will discuss converging evidence from these various strands of neurolinguistic research, and its implications for the status of the native language in a multilingual brain.

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Aphasia and language organization

For over a century, the primary way we learned about language organization in the brain was from studies of aphasia acquired after injury to the language areas of the brain – war injury, strokes, even tumors. The logic of the argument is the following: in the normal brain, language works seamlessly. But when language breaks down, the modular nature of language may be revealed. Language breakdown is generally systematic, with some components spared, and others impaired. Subtractive methodology permits us to see the structural components. The general assumption is that brain damage does not create new ways of processing language but rather reveals, through what is destroyed, components of language processing. When we observe that certain structural components of language are consistently impaired following damage to particular brain areas, we conclude that those brain regions are responsible for – or at least involved in – those language abilities in the healthy brain. It was this logic that led Paul Broca (1861) to propose that the third frontal convolution of the left hemisphere was involved in deficits in spoken language. This thinking was also behind Wernicke’s (1874) conclusion that an area in the posterior limits of the Sylvian fissure in the first left temporal gyrus was responsible for comprehension of spoken language.

Polyglot aphasia

Early neurolinguistic studies were based in France, Germany, and, to a lesser extent, England – lands full of multidialectal, multilingual people. Several cases of polyglot aphasia began to pique the interest of scientists in the next decades. Researchers began to document patterns of language breakdown and recovery in patients who had been premorbidly multilingual.

For over a hundred years of research into polyglot aphasia, two questions have been the focus. First, are all of a polyglot’s languages similarly affected by brain damage? It is sometimes
the case that multiple languages are lost to the same extent, and are regained simultaneously. Nonparallel restitution is the more intriguing pattern of recovery, however, where one language is restored before the rest, and may recover to a fuller extent than the other languages. Indeed such cases are most frequent in the literature, though not in real life! Secondly, if differential recovery does occur, what are the characteristics of the language that returns first? Answers to such questions should provide insight into the representation of a polyglot's mother tongue and other languages.

For these cases of differential recovery, neurolinguists have investigated characteristics that might predict which of a patient's languages will be the first to recover. Some of the factors that have been hypothesized include whether a language was the mother tongue (Ribot, Freud), the language most used around the time of the infarct (Pitres), the language that is most practical at the time of recovery (Bay), or the language motivated by unconscious affective factors (Minkowski). The first two factors (order of acquisition and familiarity at the time of the accident) have received the most attention and support in the literature, and these will be the focus of our discussion of polyglot aphasia.

What has come to be known as Ribot's rule predicts that the language that was learned first will be the first to recover, and will be less impaired than the other languages. Von Mundy's (1959) report of the case of JP illustrates this rule: JP was born and raised in Slovenian-speaking villages until he was recruited for military service in the German-Austrian infantry, where he learned German. After twelve years of military life, he settled down in the Austrian town of Admont, and, according to his son, had no opportunity to speak Slovenian for forty years. After a stroke in the left cerebral hemisphere, JP began speaking only his mother tongue, Slovenian.

Findings from this case are consistent with the views of Freud, who trained with the French neurologist Jean-Martin
Charcot. Speaking of the saliency of the mother tongue in his monograph *Zur Auffassung der Aphasie* (1891), Freud stated: “It never happens that an organic lesion causes an impairment affecting the mother tongue and not a later acquired language” (Freud 24). According to Freud, the superimposed associations of a second language were more vulnerable to damage than the primary language.

However, as the polyglot aphasia literature grew, more cases were reported in which the mother tongue was more affected and slower to recover than other languages. Pitres, tried to reconcile this seemingly contradictory evidence in the literature, and proposed that polyglots’ premorbid familiarity with languages was more useful in predicting their recovery patterns than the order of acquisition of their languages. Pitres’ rule states that the first-recovered language is the one that was the most familiar at the time of the accident. This may or may not be the mother tongue, of course. For example, among the seven cases described by Pitres, is the case of Jean, whose mother tongue was Béarnais patois, but who moved from the Basses-Pyrénées to Bayonne after his first communion, learned French, and thereafter spoke mostly French. After a stroke at age 48, he could express himself well in French, but found it impossible to express a thought or construct a sentence in his native tongue, Béarnais. Pitres explains that the reason the most familiar tongue is the first to recover is that it has the most solidly-fixed associations.

Obler and Albert (1977) reviewed over 100 cases of bilingual/polyglot aphasia in the literature, and evaluated statistically the extent to which for each subject the language that returned first followed the law of Pitres and/or the law of Ribot. They found that while Pitres’ rule obtained with significantly greater than chance accuracy, Ribot’s rule did not.

For several of the analyzed case studies, the language most familiar at the time of the onset of aphasia was also the mother tongue (with findings consistent with both Pitres’ and Ribot’s
rules). Recently, we have reanalyzed the data (as shown in Table 1), with the following question in mind: When the mother tongue and the most familiar tongue are not the same, which language is more likely to be the first to recover? It should be noted that for a good number of the cases in the literature, only partial information is known about the patients’ history of language acquisition, use, and proficiency in their two or more languages. Out of the 49 cases of which information about both the mother tongue and language in use at the time of the aphasia was known, 16 cases (33 %) are explained by the rules of both Pitres and Ribot and four cases by neither rule. The remaining 29 cases (59 %) are predicted by one of the laws, but not by both. Our analysis revealed that only 7 of these cases (24 % of the 29 cases) followed Ribot’s law, whereas 22 cases (76 %), followed Pitres’ law. Consistent with the Obler and Albert (1977) analysis, then, this suggests that a language learned later in life, but more used around the time of the stroke, is more likely to be the first recovered language than is the mother tongue.

We acknowledge that this belief is inconsistent with the notions of Ribot and Freud that early childhood plays a crucial role in later life. However, it does support findings in the literature on language attrition that suggest that even a native language can become lost or at least inaccessible if it is not used for a period of time while a second language is learned and retained (see Seliger, Olshtain & Barzilay). What this means about the localization of the mother tongue relative to other languages will become more evident as we learn more about how the multiple languages of a polyglot are organized. Research in polyglot aphasia is now only one of several approaches available to help us begin to answer this question.

Technologies for observing language processing

Cortical stimulation in the 1970s (and later), and brain-imaging techniques of the past few decades have permitted
researchers to directly observe multilingual brains as they process language. Due, in part, to these technologies, questions of language representation are becoming more answerable.

The field of imaging is in its youth and still somewhat unsatisfactory. Crucially for us, the weakness lies in the paucity of critical information generally provided about subjects’ proficiency (in the mother tongue or in other languages), age of acquisition of other languages, and general language history. In what follows we report an analysis of individual cases reported in the cortical stimulation and brain-imaging literature – those cases for which the most information is available. In this handful of articles, all studies provide evidence for some common areas of representation of languages in the cortex, and most report areas of separate representation along with the overlap.

Cortical stimulation

Cortical stimulation is considered by some to be a brain-imaging technique, in that the surgeon is able to map a patient’s language function. This technique is used primarily for patients who are preparing to undergo surgery for intractable epilepsy, to determine the cortical areas involved in speech and other cortical functions. Since the brain has no pain receptors, the patient remains conscious as the surgeon opens the cranium and electrically stimulates areas of the cortex. Small voltages applied to the language area typically cause a patient to become incapable of speech, or display other aphasic-like symptoms (see Caplan for explanation).

In 1978, Ojemann and Whitaker adapted Penfield and Roberts’s cortical stimulation procedures to multilingual brains, making it possible to map bilingual patients’ languages. The assumption underlying this technique is that if a brain region involved in speaking a language is stimulated during a naming task, the patient will have difficulty naming the item in that language. Rapport et al. replicated much of Ojemann &
Whitaker's electrical stimulation technique on multilingual patients in Malaysia. Case 1 of their experiment was a mathematics teacher whose mother tongue was Cantonese, but whose dominant language was English. In the naming task, the patient was shown line-drawings of depicted objects headed by the phrase, "This is a..." The patient would complete the sentence in English. The same procedure was performed in Cantonese, with the patient saying the introductory phrase and naming the object in that language.

In Figure 1 we have depicted some of Rapport et al.'s findings, using Xs to represent sites at which stimulation would produce speech errors in the mother tongue (Cantonese), and circles where L2 (English) was affected (probability of errors due to chance: less than 1-10%). In Broca's area, common sites were found for both languages, and one site caused errors in his (dominant) second language, but not in his mother tongue. Stimulation in a site in Wernicke's area, consistently produced mutism in L2 only. Individual errors in one language but not in the other (represented by the smaller symbols) were found in several spots. Stimulation in certain sites produced consistent errors in one language but only a single error in the other (in which case we have marked a smaller symbol within a larger one).

Although errors did not occur consistently in the same location for L1 (Cantonese), the fact that stimulation of certain sites did result in single errors in Cantonese and none in English suggests that there may be some independent representation in these sites. It must be noted that other cases in the study were less clear, and inconsistency between text and figures in much of this literature renders results difficult to analyze.

In considering the implications for mother tongue, it is important to note that differences are subtle within the language area. However, the same general pattern (some sites of overlap, some differential representation) has also been reported in other cortical stimulation studies, including the previously-mentioned
experiment by Ojemann and Whitaker, and Haglund et al.'
study of a bilingual speaker of English and American Sign
Language.

Other brain imaging

In recent years, less invasive technologies such as functional
Magnetic Resonance Imaging (fMRI), Positron Emission
Tomography (PET) scans, and Evoked Response Potentials
(ERPs) have been advanced to the point of being used for
research purposes on neurologically intact individuals. Such
techniques have permitted neurolinguists to ask more refined
questions about languages in the brain.

In fMRI studies, magnetic resonance images are
photographed rapidly enough to provide images of on-line
language processing (see Obler and Gjerlow 1999 for
explanation). In an fMRI study of bilinguals, Kim et al. present
vivid images of common and differential language processing,
as well as a strong case for the importance of age of acquisition
for the representation of languages in bilinguals. Participants
were divided into two categories: early and late bilinguals.
Early bilinguals were those who had been exposed to two
languages in infancy, and had spoken both of their languages
continuously and regularly since acquisition. Late bilinguals
had started learning their second language at a mean age of 11.2
years. Ten languages were represented in the study.

Participants were asked to silently generate sentences
describing events of the previous day. A participant would be
instructed in which language to perform the task, whereupon 30
images of different slices of the brain were obtained. (A
limitation in several of these technologies is that any movement
in the head generates poor images, therefore silent tasks are
used rather than speech).

When the representation of languages within early bilinguals
was compared to that of late bilinguals, the results were
striking. In Broca’s area, if both languages were learned early, they were represented in common cortical areas, whereas if a second language was learned in adulthood, it was separated from the native language. In Wernicke’s area, regardless of when the language was learned, little or no separation of activity was found. We would add that since this was a production task, activity characteristic of Wernicke’s area for comprehension tasks may not be expected. Cortical stimulation and brain-imaging studies generally support Kim et al.’s differential processing hypothesis in providing evidence for some sites of separate representation for multiple languages, and even timing differences in the processing of first and second languages (see ERP study by Ardal et al.).

To our knowledge, there is just one study that has reported no differential representation of bilinguals’ languages. The study by Klein et al. (1995) used the relatively new technology of PET scans to investigate cortical areas involved in L1 and L2 processing. Their conclusion that a language learned later in life is represented in a common area with the mother tongue has raised criticism from researchers (e.g., Kim et al. 1997, Dehaene et al. 1997), primarily because PET scans have serious limitations as tools for processing studies. In PET studies, variability may be lost because all of the subjects’ results are averaged (as opposed to the single-subject analyses used in fMRI).

Results of an fMRI study by Dehaene et al. suggest that inter-subject variability does indeed characterize L2 processing as opposed to processing of the mother tongue. As shown in Figure 2, listening to stories in L1 (French) activated sites near Wernicke’s area in all eight listeners in their study. Listening to L2 (moderately proficient English, learned after age 7) activated an extremely variable network of right and left frontal regions, ranging from classic left lateralization to exclusively right lateralization. The authors suggest that the frontal activation found in the L2-listening task might be due to the internal rehearsal of English words in working memory during
processing. As we can now see, researchers are not only asking whether languages in a polyglot may have partially separate representation, but also why L2 might recruit some different regions of the brain from those occupied by L1.

In addressing our question about the organization of the mother tongue relative to other languages, we have looked at findings in the literature of aphasia, cortical stimulation, and brain imaging. From the aphasia literature we can conclude that the mother tongue may not be a polyglot’s most resilient language. In fact, it appears that the language most used around the time of the insult will be the first to recover after brain damage. However, these findings should be viewed with caution since so little information is available regarding the ways in which the mother tongue had been used over the decades before the aphasia-producing event.

It might appear that the numerous cases of differential recovery of languages in aphasics contradict the findings in the cortical stimulation and brain-imaging literature, which show substantial overlap of L1 and L2 representation. It is important to remember, however, that most cases of polyglot aphasia are those in which patients show the same deficits and the same restitution patterns for multiple languages. These more typical case studies (which are less likely to get published than the more dramatic cases of differential recovery) are more consistent with the picture seen in the imaging studies of two languages with substantial overlap.

Clearly, an interesting phenomenon for investigators to pursue is the substantial variation across subjects in the representation of L2 (Dehaene et al.). The developing field of brain imaging will continue to shed light on such issues, as well as on the many other unanswered questions about the processing of multiple languages. For now we can make the following claim with respect to the mother tongue: while overlapping neural substrates may be required for processing multiple languages, at least to some extent, the native language may be represented uniquely.
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Table 1. First-recovered language in (premorbidly) polyglot aphasics: Cases consistent with Ribot’s rule and/or Pitres’ rule (analysis based on cases reviewed by Obler and Albert [1977]).

<table>
<thead>
<tr>
<th>Category</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consistent with Ribot’s rule and Pitres’ Rule</td>
<td>16/49</td>
<td>33 %</td>
</tr>
<tr>
<td>Consistent with neither rule</td>
<td>4/49</td>
<td>8 %</td>
</tr>
<tr>
<td>Consistent with either rule</td>
<td>29/49</td>
<td>59 %</td>
</tr>
<tr>
<td>Of those consistent with either rule, cases consistent with Ribot’s rule</td>
<td>7/29</td>
<td>24 %</td>
</tr>
<tr>
<td>Of those consistent with either rule, cases consistent with Pitres’ rule</td>
<td>22/29</td>
<td>76 %</td>
</tr>
</tbody>
</table>
Figure 1. Representation of L1 and L2, based on findings from Case 1 in Rapport et al. (1983). X indicates L1 (Cantonese), O indicates L2 (English). Small symbols denote individual errors.
Figure 2. Representation of L1 and L2 across listeners, based on findings by Dehaene et al. (1997). Xs indicates sites activated in all eight subjects when they listened to stories in L1 (French). Os indicate various sites affected in some subjects when they listened to L2 (English).
Résumé

_Perspectives neurolinguistiques sur la langue maternelle_

Dans une perspective neurolinguistique, nous nous demandons comment la langue maternelle s'organise par comparaison avec d'autres langues ? Nous considérons trois domaines expérimentaux : l'aphasie, la stimulation du cortex et la résonance magnétique.

On peut conclure que la langue la plus utilisée au moment de l'accident qui a provoqué l'aphasie est la première à faire retour. Ce peut être ou non la langue maternelle. La stimulation du cortex nous permet de tirer des enseignements qui coïncident avec les conclusions des études fMRI en mettant en évidence des substrats neurologiques superposés pour des langues multiples, alors que d'autres régions du cerveau sont uniquement sollicitées par la langue maternelle.

Abstract

_Neurolinguistic Perspectives on Mother Tongue: Evidence from Aphasia and Brain Imaging_

From a neurolinguistic perspective, we ask the following question: How is the mother tongue organized with respect to the other languages in the brain? We consider three major sources of evidence: aphasia, cortical stimulation, and brain imaging.

When aphasia occurs in multilingual speakers, neurolinguists can make inferences about the representation of multiple languages in the brain. The language most used at the time of the infarct is most likely to be the first to recover. This may or may not be the mother tongue. Data from cortical stimulation are consistent with findings in fMRI studies in revealing some overlapping neural substrates for multiple languages, along with regions recruited uniquely by the mother tongue.