Neurolinguistics of bilingualism and the teaching of languages

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Neurolinguists and language pathologists have traditionally concerned themselves with the language system, what some linguists now call implicit linguistic competence, or the grammar, which is what is typically impaired subsequent to lesions in the perisylvian classical language areas of the left cerebral hemisphere. This language system is also mainly what is taught in second language classes. But recently attention has been increasingly drawn to the fact that language, so defined, was only one component of verbal communication. Verbal communication is multimodal (i.e., involves different sensory modalities) and multimodular (i.e., each modality is comprised of a number of neurofunctional modules). At least four neurofunctionally-modular cerebral mechanisms are involved in the acquisition and use of language, first or second, subserving respectively implicit linguistic competence, metalinguistic knowledge, pragmatics, and motivation.

Linguistic competence is acquired incidentally, is stored implicitly, is used automatically, and is subserved by procedural memory. It is acquired incidentally in that acquirers focus their attention on something other than what is internalized, such as focusing on acoustic properties of sounds while internalizing the proprioception that allows them to perform articulatory movements; or on semantic and pragmatic aspects of an utterance while internalizing its morphosyntax. It is stored implicitly in that speakers are not conscious of the computational procedures that generate the sentences they produce and the underlying structure of these sentences remains forever opaque to introspection. The grammars that linguists attempt to construct are systems inferred from the systematic verbal behavior of speakers, but they have no way to know whether these constructs remotely resemble the actual computational procedures activated to generate sentences. Linguistic competence is used automatically in that it is not under conscious control: speakers could not control something of which they were not aware. It is subserved by procedural memory, as are all implicit skills. Procedural memory is task specific. Procedural memory for language relies on the integrity of the cerebellum, the striatum and other basal ganglia, and on circumscribed areas of the left perisylvian cortical region.

Metalinguistic knowledge is learned consciously, is stored explicitly, is used in a controlled manner, and is subserved by declarative memory. It is learned consciously, by noticing the items learned. It is stored explicitly, in that one can bring to consciousness the items that one knows. It can be used in a controlled manner, in that one can consciously apply a set of memorized grammatical rules, for example. It is subserved by declarative memory. Declarative memory relies on the integrity of the hippocampal system, the medial temporal lobes, and large areas of tertiary cortex, bilaterally.

Empirical evidence for these two types of memory comes from multiple double dissociations in a number of pathological conditions. Individuals with amnesia, for instance, lose access to declarative memory, while retaining all skills that rely on procedural memory. Individuals with aphasia lose access to implicit linguistic competence but not declarative memory. As a result, some aphasic patients seem to recover their less proficient L2 better than their L1, and some amnesic patients lose access to their L2. Individuals with Parkinson's Disease have their implicit linguistic competence impaired; individuals with Alzheimer's Disease have explicit knowledge impaired (Sagar et al, 1988; Lieberman et al., 1992; Ullman et al., 1997). In fact, Loss of L2 has been reported in Alzheimer's Disease, a condition in which declarative memory is first affected. (Hyltenstam & Strout, 1993).

Whereas implicit aspects of language structure, such as phonology and morphosyntax, are subserved by procedural memory, the sounds and lexical meanings of words are consciously known. In fact, vocabulary stands apart from the rest of language structure in several ways: chimpanzees and gorillas are able to learn a large number of signed words; children deprived of language input during infancy can eventually also learn numerous words but little morphosyntax; the idiot savant reported by Smith & Tsimpli (1995) had little implicit linguistic competence in his native language but was able to learn large vocabularies in several languages (as well as metalinguistic facts about the languages); and individuals with anterograde amnesia, while capable of acquiring new motor and cognitive skills, are incapable of learning new words;As mentioned, Alzheimer patients retain functions subserved by (implicit) procedural memory long after they have lost access to the functions subserved by (explicit) declarative memory—including vocabulary.

It is important to realize that implicit linguistic competence and metalinguistic knowledge are of a different nature, bear on different objects, and rely on very different cerebral structures, and that, therefore, metalinguistic knowledge never becomes implicit competence, or the other way around. Both develop independently. What may happen in the course of second language development is that the initially almost exclusive use of metalinguistic knowledge may be gradually replaced by an increasing use of linguistic competence (Paradis, 2000). But metalinguistic knowledge is not transformed or converted into implicit linguistic competence: it remains available.

Along with implicit linguistic competence and metalinguistic knowledge, two additional cerebral systems are involved in processing verbal communication: Those which subserve linguistic pragmatics and motivation. Indeed, in addition to the interpretation of the literal meaning of sentences, a discourse grammar, including rules of presuppositions and inference, and in general any extra-sentential context-dependent phenomena, is required. Sociolinguistic rules, which determine the appropriate choice among the various possible structures available in linguistic competence, are equally necessary. So is paralinguistic competence, comprising the comprehension and use of intonation, gestures, facial expressions, and anything that serves to specify the meaning of the sentence—such as whether it is meant as a sarcastic remark or a compliment, an indirect request or a factual question, whether it is to be taken with a figurative, metaphoric, idiomatic meaning or at face value. In fact, we may estimate that more than half of what we say is not literally what we mean—at least not entirely. Most of the time, we mean more than what we say, not mentioning implicatures, or something different than what we actually say, as in metaphors, idiomatic expressions, and indirect speech acts, or even the opposite of what we say, as in irony and sarcasm (Paradis, 1998).

In the literature on linguistics and the pathology of communication, there are at least two clearly distinct domains subsumed under the term structure and nonliteral meanings. Both domains have been reported to be vulnerable to right hemisphere damage while relatively preserved in the context of dysphasia (Pierce & Wagner, 1985). The common denominator seems to be the necessity to rely on context and general knowledge in order to derive an interpretation. This context can be situational (including paralinguistic cues), but also discursive (including structure and contents of discourse, as well as turn-taking and the like, from which inferences and implications must be made).

Over the past century, damage to specific areas of the left cerebral hemisphere has been reported to disrupt the comprehension and/or production of various aspects of phonology, morphology, syntax, and the lexicon. Clear deficits of a different nature, affecting the comprehension and production of humour, affect, and various aspects of the nonliteral interpretation of utterances, have been reported over the past 20 years or so (see Paradis, 1998 for a review). Deficits secondary to right-hemisphere damage typically involve those aspects of language use other than the ones involved in the literal interpretation of (context-independent) sentences. More specifically, patients with right-hemisphere damage have been variously shown to be insensitive to connotative meaning, figurative speech, even when supportive contextual cues are available, metaphors, the emotive meaning of words, emotions that have to be inferred from context, and indirect speech acts. Many have been reported not to be able to use prosody to interpret (or convey) emotional content. They also fail to understand the moral, punchline, theme, or main point of a story and have problems in the organization of discourse. Overall, these patients seem to have difficulty in using contextual information to interpret discourse.

Nevertheless, the role of the right hemisphere in language processing has not been investigated as thoroughly as that of the left hemisphere. Thus, whereas deficits in implicit linguistic competence have long been commonly referred to as *aphasia* (or, more etymologically accurate, and still current in British English, *dysphasia*) there was no label to refer to impairments in the ability to infer what is meant from the contexts in which something is said. I have therefore proposed to use the term *dyshyponoia*, from the Greek uJponowv (to grasp what is *sous-entendu*), albeit unsaid in an utterance) to refer to a difficulty in drawing appropriate inferences from extra-sentential information, leading to problems in the interpretation of the unspoken component of an utterance, i.e., its illocutionary force or pragmatic component, with preserved comprehension of the literal meaning of a sentence, i.e., its semantics, derivable solely from the lexical meaning of words and morphosyntactic structure of the sentence (Paradis, in press).

Last, but not least (Damasio, 1994, 1999), the cerebral system underlying emotion also plays an important, if neglected, role. The structures of the limbic system that subserve emotions, drives and desires, are phylogenetically and ontogenetically anterior to the development of higher cognitive systems. Twenty-five years ago, Lamendella (1977) suggested that implicit linguistic competence was integrated within the limbic system (involving the striatum and amygdala), whereas metalinguistic knowledge was not. Schumann has repeatedly emphasized the importance of motivation, and in particular the role of the amygdala and the dopaminergic system in the acquisition of language (Schumann, 1990, 1994, 1998). One important difference between first and second language appropriation is that the first phase of the microgenesis of an utterance, namely the desire to communicate a message, is mostly missing in the learning of an L2 in a school environment (Paradis, 1992), resulting in a lack of dopamine release (Schumann, 1998). Evidence of the impact of motivation on language processing comes from dynamic aphasia, when patients with spared language representations nevertheless remain speechless unless persistently prompted, and the reverse, when global aphasics, who are unable to put two words together, manage to blurt out a relatively complex utterance when strongly annoyed or otherwise emotionally aroused. The impact of motivation on L2 learning has also been well documented, showing that both instrumental and integrative motivation have a facilitating effect on L2 appropriation, and that the impact of integrative motivation is stronger (Lambert, 1969), probably because it also encourages more extensive practice.

This leads us to another component of the cerebral system underlying communicative competence, which is not associated with a particular anatomical area or functional system, but is associated with all higher cognitive functions, irrespective of their domain, namely, the activation threshold. The neural substrate of any mental representation requires a certain amount of impulses to reach activation. Each time an item (word, morphosyntactic construction, or whatever) is used, its activation threshold is lowered, making it easier to activate again; but it slowly raises when inactive, as reflected in recency, frequency and practice effects, and in attrition.

Practice in communicative environments is what internalizes the grammar. That is, repeated exposure to, and use of, sentences of a certain type, lead to the acquisition of the implicit computational procedures that eventually allow for the automatic comprehension and production of sentences of this form. (These procedures may be algorithms such as the generative grammars constructed by linguists, or frequency-of-co-occurence-based relational networks, as described by connectionist psychologists, or articficial intelligence neural netwwok constructs with weighted connections. But to date, there is no criterion to decide which type of grammar or parallel distributed processing is more compatible with the way the brain actually processes information.) Strong motivation may have the same effect as practice by lowering the activation threshold.

To conclude, verbal communication involves different modalities (aural, oral, visual, gestural) and each modality is comprised of a number of independent but collaborating neurofunctional modules. At least four cerebral mechanisms are involved in the acquisition and use of language: Implicit linguistic competence, metalinguistic knowledge, pragmatics, and motivation. Unilingual and bilingual speakers alike rely on all four systems. However, to the extent that L2 speakers have gaps in their implicit linguistic competence, they will compensate by relying more extensively on metalinguistic knowledge and pragmatic aspects of verbal communication, both in speaking and understanding. Their motivation will modulate the efficiency of the various cerebral systems involved. Since different cerebral structures underlie each of the four systems, pathology may selectively affect L1 or L2 depending on which cerebral structures are affected, so that some aphasic patients paradoxically recover their premorbidly weaker L2 better than their L1, and patients with Alzheimer's Disease lose access to their L2 before their L1.

To the extent that a language is acquired incidentally, it will be represented as automatically usable implicit competence (and the more so, the younger the individual); to the extent that it is learned formally, it will be represented as metalinguistic knowledge usable in a controlled manner (and the more so, the older the individual). Therefore, the more formal the learning method, the more the second language will rely on declarative memory; the more communicative the method, the more the second language will rely on procedural memory. Some second language speakers are able to speed-up their control over production (Favreau & Segalowitz, 1983; Segalowitz,1986; Segalowitz, 2000; Segalowitz & Segalowitz,1993; Segalowitz., Segalowitz, & Wood, 1998) to the extent that they can fool most of the people much of the time into believing that they are native speakers of the languages. But stress, fatigue, aging, clever psychological experiments or one too many martinis will soon expose them and show that their use of L2 is controlled to a much greater extent than their L1—even though possibly considerably speeded-up.

This does not mean that metalinguistic knowledge is not useful. There are two ways of speaking: The controlled way and the automatic way. Individuals with genetic dysphasia, autism and Down Syndrome rely to a great extent on the controlled use of metalinguistic knowledge, as do many incipient second language learners. Since adults tend to use declarative memory (metalinguistic knowledge) anyway, it may be useful to provide them with an explicit description of particular grammatical phenomena. This may, in turn, help them not only to construct correct sentences (in a controlled way), but also to monitor and self-correct their production (the output of their implicit competence) and, by thus practising the correct forms a number of times, may contribute towards eventually internalizing them (in whatever form the implicit underlying computational procedures may take).

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