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Review

Neurolinguistic Findings on the Language Lexicon: The Special Role of Proper Names

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Abstract

Cognitive linguistics proposes the existence of a human language lexicon as a necessary subsystem of language production and comprehension. While the inner structure of the lexicon remains speculative, measures of its function may distinguish separate processing paths for different types of lexical entries. Based upon the presented findings on nomina from reaction time measurements, event-related potentials (ERP) analysis, and functional magnetic resonance imaging (fMRI), the special role of proper names in language – in contrast to common nouns – appears to be grounded in a neurocognitive reality.

Key Words: language, first names, lexicon, EEG

Introduction

How phonological, lexical, and conceptual knowledge of language is represented in the human brain is a major issue in cognitive science. Knowledge of the inner structure of the cognitive lexicon is essential to the theoretical foundation of many applied fields, *e.g.* language learning, language therapy of aphasics, and computer-based communicators in artificial intelligence (*e.g.* 33). Investigating the language system and analyzing the structure of the assumed sub-components of the language capability has been a hot topic for well over 2,000 years, especially in language philosophy and, more recently, in linguistics. Both disciplines developed a highly complex building of hypothesis, models and theories based on introspection and logic. Later, collection of empirical data for research of different languages in comparative linguistics was undertaken. Looking at the methods used in the field of linguistics, one may distinguish at least three points of expansion:

– Introspection as knowledge source: Most major theory in linguistics has been deeply influenced by classical findings, discovered over the last 3,000 years (if we only look as far back as the ancient Greek and Roman cultures).
– Psycholinguistic techniques: Over 50 years ago, psychologists and linguists introduced empirical techniques such as reaction time measurement for studying language processes. To this day, psycholinguistic research influences our knowledge of language processing as a major technique using highly sophisticated experimental designs (*e.g.*, eye tracking) combined with advanced statistics.
– Cognitive neuroscience: Over the last three decades cognitive neuroscience progressed by unprecedented leaps *via* an explosion of new techniques. Meanwhile, non-invasive electrophysiological techniques such as electroencephalography (EEG) and brain imaging techniques such as positron emission tomography (PET) and functional magnetic resonance tomography (fMRI) offer incredible insights into the working brain which nobody could have foreseen a quarter century ago.

Today, the field of cognitive neuroscience is continues in this rapid expansion. Putting this in perspective is the fact that most studies investigating complex, naturally spoken sentences are not yet ten years old. The technique of event-related functional magnetic resonance imaging (fMRI) was developed during the last 15 years and new approaches will continue to proliferate. Additionally, promising novel methods like diffusion tensor imaging (DTI), transcranial magnetic stimulation (TMS) and optical tech-

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niques such as near infrared spectroscopy (NIRS) have emerged and are leading to new insights into language-related processes in the brain. In lieu of this rapid progress, it is already clear that over the next 30 years, cognitive neuroscience will influence our knowledge of language in ways so profound we can only begin to estimate its impact. However, how language is organized in the brain is still an open question. What does this hypothetical lexicon look like, though? In this article, I present findings of neurolinguistic experiments on processing of proper names we carried out in our lab.

Processing of Spoken and Written Proper Names

A Psycholinguistic Approach Using a Semantic Decision Task (Reaction Time Paradigm)

From a cognitive linguistics point of view, language ability is held to be based not on a single language system (as proposed by the Broca-Wernicke language center paradigm), but rather on a broadly distributed and modularly constructed system of components, not all of which need be language-specific. A possible member of this proposed set of components is a mental lexicon. On one hand, even granted the existence of a lexicon, it is neither clear whether there would be a single lexicon or multiple sites of lexical organization (*e.g.*, for first and second language) nor what the inner structure of the lexicon would be like. On the other hand, we can assume that the approximately 10,000 to 40,000 words a speaker knows must be organized in the brain somehow, otherwise humans would be unable to comprehend and produce the language in their environment as rapidly as they do. What might the inner structure of the lexicon be and in which way are words categorized, stored and processed in the brain?

For theoretical reasons, language philosophers, and linguists developed a system of word categories which can be traced back more than 2,000 years to ancient Greek writings. One of these categories is the group *nomina propria* within the class of concrete nouns (*e.g.* 1, 2, 7). There is an ongoing discussion in language philosophy as to whether proper names are a special group of words (11, 17), and if so, exactly which belong to this set (*e.g.*, first names, geographical names, brand names, *etc.*)? From a neurolinguistic perspective, one asks whether word categories such as "verb", "noun", or, in particular, "proper names" are artificial or, in fact, reflect a cognitive or even a physiological reality. If, for example, the storage, use, and processing of proper names were to involve different neural networks than common nouns, the special status of proper names, proposed for theoretical reasons, would have a physiological basis. Taking a psycholinguistic approach, one can investigate a hypothetical processing difference between two word classes in a behavioral experiment.

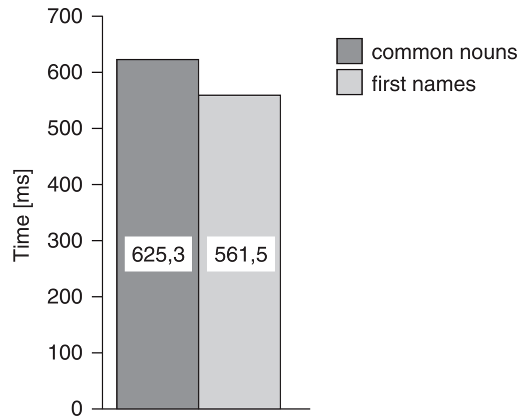

Fig. 1. Mean semantic decision times in milliseconds for 60 common nouns and 60 first names visually presented to 40 native German subjects, showing a significant reaction time difference between the tested words (*t*-test with Bonferroni correction, $P = .001$) (Reference No. 38, Werner and Müller, 2001).

In a semantic decision task, we had 40 subjects listen to or read 60 common nouns and 60 first names, presented randomly. They were asked to decide whether each stimulus was a name or noun by pressing the respective "name" or "noun" response button. By measuring the decision time (reaction time) of the button-press, a possible dissociation may be determined. All stimuli were matched for psycholinguistic variables like syllable length, articulatory duration, imaginability, word frequency and familiarity. The familiarity of the participants with individual names was tested in a post-experimental questionnaire. For the tested German first names and common nouns, we found a difference in the semantic decision time as is shown in Fig. 1. Proper names led to a significantly shorter reaction time (38). In addition, the faster semantic decision for names corresponded with a much smaller error rate of 3.5% for names and 6.6% for nouns.

In a comparable semantic decision task experiment in which 40 native Mandarin speakers listened to and read a total of 280 different words (80 common nouns, 80 first names, 80 geographical names, and 40 brand names), we found that recognition of proper names was significantly faster than that of common nouns, independent of the modality (visually and auditorily) by which the stimuli were presented (41). This was true for the first names and geographical names being tested, whereas the group of brand names required approximately the same decision time as the common nouns. To summarize, the results of this

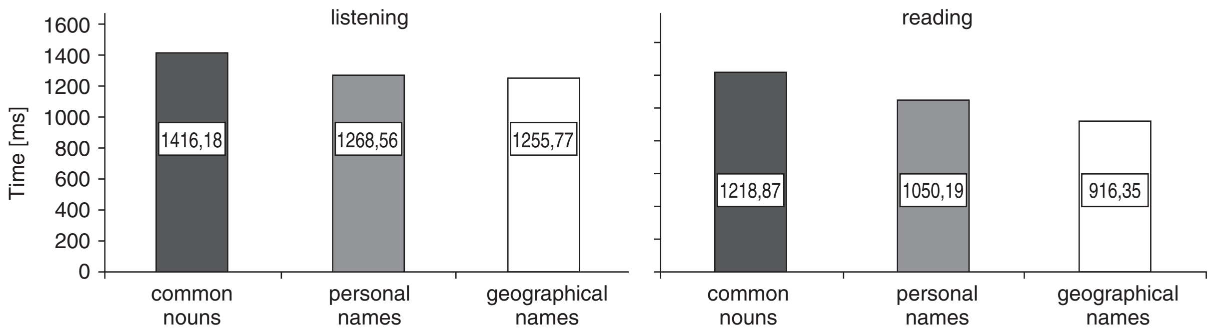

Fig. 2. Mean semantic decision times in milliseconds for 75 auditorily and 99 visually presented Arabic names and nouns. We found a significant time difference between the tested common nouns and both subgroups of names in both modalities (*t*-test with Bonferroni correction, *P* = .0001) (Shoblag and Müller, unpublished).

experiment indicated a cognitive or physiological difference between the tested prototypical names on the one hand and common nouns and brand names on the other.

To further test this hypothesis in a second non-Indo-European language, we performed the same experiment (38, 41) with 29 native monolingual Arabic speakers from Morocco. Using 174 auditorily and visually presented stimuli in Modern Standard Arabic, we again found a significant difference in processing time between common nouns on the one hand and personal and geographical names on the other (see Fig. 2).

To summarize the results of our behavioral experiments on proper name processing, our semantic decision task tested 110 subjects on 576 stimuli across three languages (German, Mandarin, and Arabic) and found a clear dissociation between common nouns and proper names.

Investigating Proper Names Processing with Electroencephalographic Techniques (EEG)

Analysis of Event-Related Potentials (ERP-Analysis)

Studying language comprehension in terms of its underlying physiology by recording an electroencephalogram (EEG) followed by analysis of event-related brain potentials (ERPs) is a useful method, as it provides more direct and less subject-influenced data than behavioral studies.

In search of additional evidence for a physiologically indicated special status of proper names, we carried out an EEG experiment comparing the comprehension of different lexical classes within complex sentences, presented as naturally spoken language. Evidence already existed for effects related to different word categories, *e.g.* noun and verb meanings of homophones (differences within the first 350 ms) (6), open-class (nouns, verbs, most adjectives) *vs.* closed

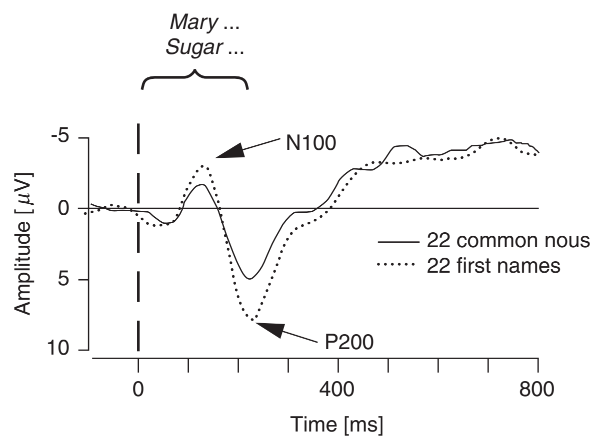

Fig. 3. Grand average waveforms of the ERP at the electrode position Cz for all 32 subjects tested in this EEG experiment. Shown are the first 800 ms of ERPs elicited by 22 sentences, each beginning with either a first name (dotted line) or a common noun (solid line). The vertical dashed line indicates the beginning of the sentences (100 ms prestimulus time). A significant difference in amplitude of the N100 and the P200 components between first names and common nouns was found (Reference No. 24, Müller and Kutas, 1996, Reproduced with permission from Wolters Kluwer Health, September 24, 2010).

class words (pronouns, articles, conjunctions, prepositions) (18), concrete *vs.* abstract words (37) or verb categories (30). The aim of our study was to look for a specific ERP-morphology related to the processing of either *nomina appellativa* (various concrete nouns) or *nomina propria* (here: people's first names) as first words of naturally spoken sentences. Our hypothesis was: If common nouns and names are stored in different lexicons and/or different brain regions, or are processed differently at different levels in language comprehension, then one might expect a dissociation in physiological data like ERPs.

To test for this proposed difference, 32 native English speakers, University students between 19 and

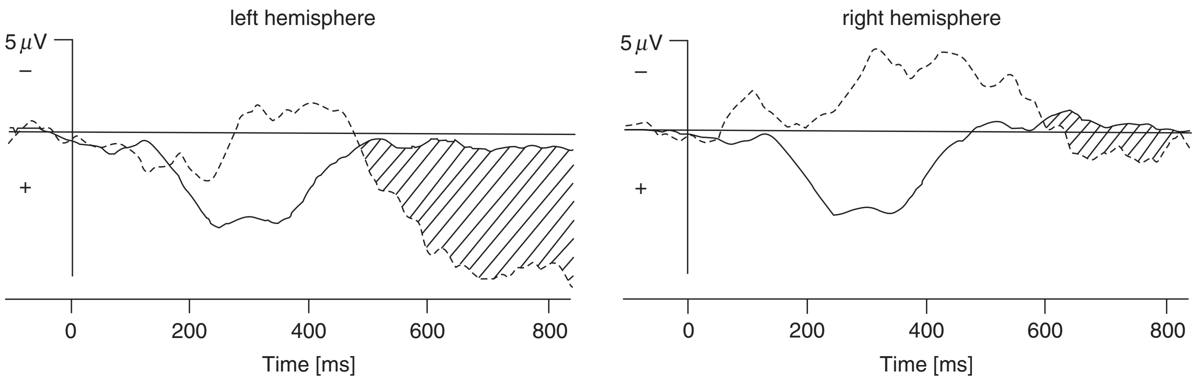

Fig. 4. Listening to the subject's own name (broken line) in comparison to other first names (solid line) elicits a late left hemispheric positivity in the ERP, shown here for F7 *vs*. F8. The negativity around 400 ms, which is strongest at Pz, is still present (Reference No. 24, Müller and Kutas, 1996, Reproduced with permission from Wolters Kluwer Health, September 24, 2010).

35 years of age with normal hearing abilities (pure-tone audiometry) took part in the following experiment. Subjects were seated on a recliner in a sound-proofed booth and listened to a total of 216 sentences of varied syntactic structure, among which 44 target sentences beginning with either a common noun or first name were distributed, while their electroencephalogram was recorded. As demonstrated in Fig. 3, the ERPs elicited by sentences which began either with a proper name or a common noun have basically the same wave shape, which can be taken as an evidence for the basic equivalence of the stimuli used in this experiment. Although the articulatory duration of the 44 *propria* and *appellativa* ranges from 212 to 1148 ms and 311 to 738 ms, respectively, they share a very similar morphology of ERP time course aside from the amplitude of the N100 and P200 components. The primary difference between nouns and names is the larger amplitude of these components for names at the electrode positions Fz, Cz, and Pz as well as at the posterior-lateral sites. The results of this study suggest a difference in the physiological basis of comprehension of *propria* and *appellativa* as early as 120 ms (N100) after the articulation onset (24). Likewise using the ERP technique, a functional difference in the retrieval of proper names and common nouns was shown (29).

The name with the most monoreferential use is one's own name and its special status has been confirmed by several studies. In a monaural localization task, subjects' own names were localized faster then other first names (27). As early as 4-5 months old, infants turn their heads more often to the direction from which their own name is presented in comparison with other first names (19). Even during sleep, a differential response to the subject's own name, relative to any other proper name, persists (3). In comparison to other first names, the presentation of the subjects' own names elicited a prominent negativity at parieto-central sites (peaking at 400 ms) and a broad positivity (500 to 800 ms), especially at left hemispheric lateral-frontal sites (see Fig. 4) (24).

Spectral Analytic Techniques (EEG Coherence Analysis)

By analyzing ERPs, we are able to measure the amplitude of the summated electric potential of at least 40,000 neurons in response to a given event (here: first names *vs*. common nouns, spoken). An alternative approach to analyzing the electrical activity of the brain is EEG coherence analysis, in which the neural synchronicity within specific frequency bands is examined. This spectral analytic technique is suited to detecting synchronous electrical patterns in neuronal networks. Since temporal synchronization of such large neuronal cell assemblies within specific frequency bands is seen as one major phenomenon of neural systems driving language processing (36), we measured synchronization of large brain areas by computing EEG coherences and analyzing differences in the cortical interaction between name and noun processing. Using this approach, high coherence between two EEG signals is interpreted as high co-operation and synchronization between underlying brain regions within a given frequency band. Such a difference supports the view of a physiologically based dissociation between the two conditions tested, *e.g.* postulated processing differences between two word classes.

We conducted an EEG experiment with 25 native German students listening to 80 critical words, 40 common nouns and 40 first names distributed among a total set of 200 words. The EEG was recorded during the perception of these randomly presented names and nouns and spectral parameters such as amplitude and coherence were computed for the frequency bands (26, 36).

As Fig. 5 shows, names elicited an EEG coher-

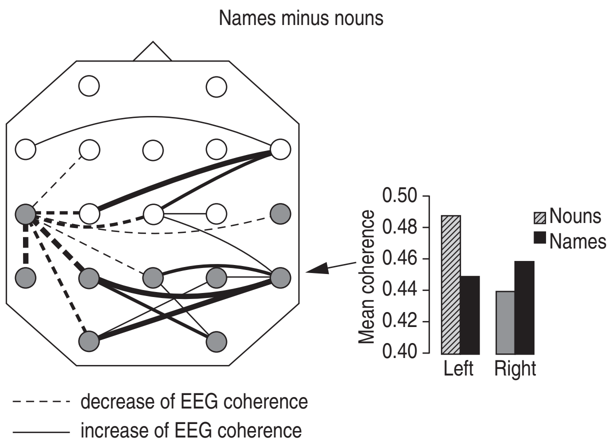

Fig. 5. EEG coherence changes when listening to first names compared to common nouns (processing of first names minus processing of common nouns). Schematic view of the head (top view) showing the electrode positions used in the EEG experiment (circles) with the delineated EEG coherences changes. Shown are the EEG coherence differences between name and noun processing for 25 native German subjects listening to 40 first names and 40 common nouns. Full lines indicate higher coherence and dashed lines indicate lower coherence for proper names. The inset shows the significant mean coherence differences for names (black bars) and nouns (grey bars) at posterior electrodes (filled circles) (Reference No. 36, Weiss and Müller, 2003).

Fig. 6. Lateral view of the left (L) and right (R) hemisphere showing the neural activity pattern evoked by first name processing in the comparison names minus nouns. Both temporal lobes and areas in the right hemisphere show significant differences (Reference No. 40, Yen *et al.*, 2005).

ence increase in the alpha-2 band (11-12 Hz) at right temporo-parieto-occipital electrodes and pronounced interhemispheric coherence also increases, whereas nouns elicited a coherence increase at left temporo-parietal sites. In comparison to common nouns, the processing of proper names elicited differences in cortical interaction depending on the frequency band and topography studied. The results of this study, carried out utilizing an alternative EEG analysis method along with stimuli from a different Indo-European language, lend additional support to the special role of proper names.

Brain Imaging with Magnetic Resonance Tomography (fMRT)

Looking for brain regions involved exclusively in the processing of proper names, we conducted a brain imaging study using functional magnetic resonance imagery (fMRI). In this experiment, 12 native speakers of Mandarin Chinese listened to 40 first names, 40 geographical names, and 40 common nouns while their brains were scanned. It has been suggested that the right hemisphere is more favorably disposed to the referential processing of proper names (35). Based on the findings of the EEG coherence study (see Fig. 5), we expected that proper names would elicit higher synchronization at right posterior sites within the alpha-2 band (11-12 Hz). Analyzing the processing difference of the critical words with the fMRI-technique (the processing of first names minus the processing of common nouns) would reveal activity patterns typical for first names only. Our hypothesis was that compared to common nouns, processing names would evoke more than strictly language-related brain activity and would recognize additional or possibly altogether different cognitive brain activities. Our results show that processing of proper names activates not only the usual brain regions in the left hemisphere but also regions such as precentral gyrus, superior temporal gyrus, lingual gyrus and some subcortical areas in the right hemisphere (40). The names-selective activation in the right hemisphere may indicate that besides language related processes other cognitive processes, such as *e.g.*, face recognition, may be involved (see Fig. 6).

Speaking Proper Names

The ERP data presented in chapter 2.2.1 (see Fig. 3) show a difference in comprehension of the first word of naturally spoken sentences beginning with either *propria* or *appellativa*, as early as 120 ms following the onset of articulation. This appears reasonable for critical words with a total articulatory length of approximately 200 ms, but it is very early for those names and nouns with durations longer than 500 ms. This means that hearing one to two phonemes of the critical words already evoked a difference in the listener's brain. A possible explanation for these early differences could be a physical difference in the sound articulation at the very beginning, already indicating a proper name or common noun. Such a marker could be realized at least two ways: 1. The initial phonemes of first names differ systematically from those of common nouns (*e.g.* by onomatopoesis), 2. Knowing that the sentence will start with a first name, the speaker unknowingly provides hidden clues about the sentence subject, *e.g.* in terms of intonation.

Both explanations would allow such a fast brain response to first names and common nouns perceived auditorily.

To test the possibility of there being some perceptible physical difference between name and noun articulation, we conducted a behavioral gating study (13) with English nouns, were only the beginning of a spoken word is presented to the participants. The participants were, in fact, much better than chance in guessing whether a stimulus was a common noun or a proper name after listening to only the first 120 ms of it (25). This makes our findings of early ERP-differences during sentence comprehension (see Fig. 3) less surprising. Following the cohort model, after the recognition of only two phonemes, the average number of possible English words compatible with the input is reduced to approximately 40 (21). In that study, we found that the initial 120 ms of English words provides sufficient information to reveal whether an articulatory string is the beginning of a noun or a name (24, 25).

In a follow-up German study using the same gating paradigm and presenting only the first 100 ms chunks of 40 first names and 40 common nouns to 40 subjects, we obtained similar results. Even in the German experiment, the subjects guessed significantly better than chance as to whether a stimulus was a common noun or a proper name after hearing only the first 100 ms. The successful guessing rate was very high after hearing the first 160 ms including the first two to three phonemes of the stimulus words. In this study, we also used nonnatural computer-synthesized words for testing. As Fig. 7 shows, this works only for naturally spoken names and nouns; words synthesized by computer did not yield correct "name" decisions at above-chance rates (38).

To test this result using a nonbehavioral method, we employed electrodermal response (EDR), measuring the electrical resistance of the skin while presenting the 160 ms chunks of the names and nouns to 40 subjects (31). Because hearing the names of well-known persons elicits an EDR due to their emotional-affective load, we could show, that 160 ms chunks of first names were uttered significantly differently from common noun chunks. This finding supported the hypothesis, that spoken names carry a physical marker right from the beginning of the articulation.

To investigate what kind of phonetic information in spoken first names might lead to this early decision between names and nouns, we did a phonetic analysis of the stimulus items used in the German gating experiment. *Via* LPC analysis, we extracted the frequency values of the first two formants of the first vowel of the tested names and nouns, finding that the frequency of the second formant (F_2) was generally significantly higher for the German first names tested than for common nouns (4). In addition, it is known that the choice and use of given names reflect acoustic properties and aesthetic impressions affecting parents' preference for certain phoneme combinations when naming their children. In English, for example, male first names are phonologically very similar to common nouns, whereas female names reveal a significant difference in the phonological structure. These are characteristically longer, exhibiting weak initial syllables and stressed vowels with [i] with higher frequency (9). Studies on other languages provide additional evidence of phonetic features which distinguish first names from common nouns (16, 20). In combination with the fact that given names are very often selected for their phonetic properties, the articulatory difference we found could be used by the listener as a very early hint that a personal name is involved.

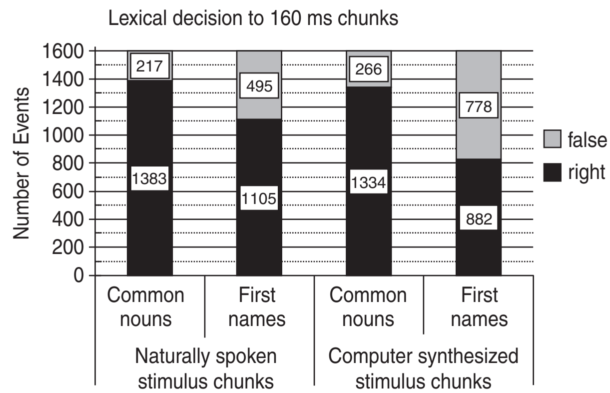

Fig. 7. The absolute number of right and false decisions of 40 subjects to the first 160 ms of auditorily presented names and nouns in a semantic decision task. Subjects listened to naturally spoken and synthesized chunks of 160 ms length (40 items in each group = 1,600 decisions in total) (Reference No. 38, Werner and Müller, 2001).

What Does This Mean for Processing Proper Names?

The distinction between proper names and common nouns, introduced by introspection for theoretical reasons, is supported by the results of several experiments across four languages using different techniques. However, it remains unclear which names function as prototypes and what happens when common nouns are used monoreferentially. In an interdisciplinary context, a special status for names is also supported by neuropsychological findings on specific brain damage (5, 14, 39) which reduces naming ability selectively for either names (*e.g.*, 15) or nouns (23). Furthermore, proper names display a special pattern of vulnerability to memory errors during recall of familiar names and learning of new names (8, 22).

This difference between names and common nouns in relation to memory performance was addressed as a philosophical problem long before cognitive science endeavored to resolve it. The existence of the tip-of-the-tongue phenomenon (TOT) for familiar names is a topic in memory-related studies (34). The TOT state, wherein the semantic information seems not entirely lost, but access to the phonological information is impaired, occurs more frequently for proper names than for common nouns among the elderly (8).

Over the last decade, the processing of proper names has become a topic of great interest in the cognitive neuroscience of language (*e.g.*, 10, 12, 28, 32). From the neurolinguistic perspective as reported here, much of the work done in this area supports the idea that processes related to comprehension and production of monoreferentially used proper names differ from those for common nouns.

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