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The Genetic Perspective in Psycholinguistics or Where Do Spoken Words Come From?[1]

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The core issue in the 19-century sources of psycholinguistics was the question, "Where does language come from?" This genetic perspective unified the study of the ontogenesis, the phylogenesis, the microgenesis, and to some extent the neurogenesis of language. This paper makes the point that this original perspective is still a valid and attractive one. It is exemplified by a discussion of the genesis of spoken words.

THE ORIGINS OF PSYCHOLINGUISTICS

Here is the standard story about the birth of psycholinguistics: It all started with a seminar on psycholinguistics under the auspices of the Social Science Research Council, held at Cornell University in 1951. This was followed by another seminar at Indiana University in 1953, whose proceedings, edited by Osgood and Sebeok, appeared in 1965 under the title *Psycholinguistics: A Survey of Theory and Research Problems*. These seminars brought together leading psychologists, linguists, and anthropologists, who jointly defined the new interdisciplinary field. The emerging discipline soon got a new twist when young Noam Chomsky stirred up the cognitive revolution during the late 1950s. Mentalist generative grammar set the agenda for George Miller's research strategy: the experimental study of our sheer limitless productivity in understanding and producing language.

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There is little wrong with this often repeated story, except that it ignores the more distant origins of psycholinguistics. In fact, each of the pioneers involved in this recent history of our field was well aware of those more distant and more complex origins (as appeared to me from personal communications with many of them, and from a host of references in their publications). But to establish identity in a field, it is always helpful to simplify history, to create a half-page saga that can be easily recounted from textbook to textbook.

The psychology of language (the original name for the discipline, and still a useful synonym of "psycholinguistics") was invented by linguists halfway through the 19th century. When, after the period of Idealism, logic lost its ground as a basis for the understanding of grammar, linguists began to view language as a spontaneous product of nature. Language is a natural product of consciousness, according to leading 19th-century linguists such as Herder, Steinthal, and Lazarus. The great challenge for linguistics is to explain the origin, structure, and variety of languages as arising from an "Ursprache," spontaneously generated by human awakening consciousness. That romantic, evolutionary perspective shifted the weight of explanation in linguistics to psychology. "Fortunate advances in linguistics presuppose a developed psychology,"[4] wrote Heymann Steinthal in 1855. Knoblauch (1988), in his thorough account of this early history, showed that, regrettably, such a "developed psychology" simply didn't exist. Steinthal had little else than Herbart's atomistic individual psychology to refer to, and the occasional self-proclaimed psychologist of his time simply wasn't interested in this kind of challenge. In other words, the "psychology of language" was invented by linguists *pour besoin de la cause*—it was little else than linguistic folk psychology.

But matters changed when Wilhelm Wundt did take up the challenge, beginning in the 1880s and eventually resulting in his two-volume *Die Sprache* of 1900. For Wundt too, the principal aim was to explain language and languages as a spontaneous product of consciousness, as an expression of mind. The ultimate linguistic explanandum was the phylogenesis of language and Wundt set out to create a theory of microgenesis, the generation of words and sentences in the individual mind, to provide the theoretical foundation. Modern psychology of language began with a theory of speaking. Still, even Wundt argued that the phylogeny of language cannot be fully explained from microgenesis. It needs a society to affect, to shape, the individual mind. The psychology of language is part of *Völkerpsychologie*. This is particularly clear from Wundt's picture of ontogenesis. Different

[4] Translation of the following: "Gluckliche Fortschritte in der Sprachwissenschaft setzen eine entwickelte Psychologie voraus." (Steinthal, 1855).

from most of his contemporaries, Wundt did not consider child language, in any of its early stages, as a creation of the individual child. In page after page, Wundt argued that first words and their articulations are just imitations.

I will not further dwell on Wundt's grand tour-the-force of eventually explaining the phylogeny of language from a universal, original sign language (still observable in "the" sign language of the deaf). The point I want to make is that the original perspective of psycholinguistics was a genetic one. Where does language come from, phylogenetically, microgenetically, ontogenetically, and—only occasionally discussed by Wundt, but a lot more by his contemporaries, such as Wernicke—neurogenetically? That perspective has, in my opinion, not lost any of its attractiveness. In the following I will exemplify it by discussing the origins of spoken words.

THE GENESIS OF SPOKEN WORDS

Readers of the *Journal of Psycholinguistic Research* need not be reminded of the fact that we, *homo sapiens*, are fanatic speakers. Most of us talk for several hours a day, and when we are not chatting with others, we are probably talking to ourselves. Where does this torrent of words come from? The answer depends on the genetic perspective one chooses. From the phylogenetic perspective, one should wonder why our closest relatives in evolution never exchange a word, whereas we have become indefatigable story tellers. What features of cognitive architecture enable the evolution of a mental lexicon? From the ontogenetic perspective, one might wonder how this functional architecture gets established so early in life that the *word spurt*, the explosive acquisition of several words a day, can start by the age of a mere 18 months. One can also wonder how the brain prepares the utterance of words. Although this has been a core issue in aphasiology since the pioneering work of Wernicke, Broca, and other 19th-century neurologists, modern brain imaging methods now allow us to approach this question in entirely new ways. Finally, one may take the classical cognitive psychological perspective and study the mental microgenesis of words. Can one create a real-time process model of spoken word generation and test it experimentally?

In an ideal world, these four perspectives should be highly cohesive. But this is not yet the case. Usually, they are independently pursued; their connections are still to be elaborated. In the following, I will sketch a few possible connections among these four perspectives. To do so, I will start from the microgenetic perspective, not only because that is what I have been spending most of my research time on in recent years, but in particular because a well-established processing model can be a helpful instrument in the exploration of the ontogenetic, neurogenetic, and phylogenetic issues in word production.

THE MICROGENESIS OF WORDS

The normal rate of speech in conversation is some two words per second, but sports reporters and auctioneers easily attain speeds of five words per second. The generative processes of individual words overlap like roofing tiles. How fast is an individual word prepared for articulation? The classical paradigm for studying this is picture naming, and the standard laboratory result is a naming latency of about 700 ms. What happens during this short period? Our research group at the Max Planck Institute has been concentrating on this problem for about a decade. The result is a detailed processing model and its computational implementation WEAVER++ (cf., among others, Bock & Levelt, 1994; Levelt, 1992; Levelt, Roelofs, and Meyer, in press b; Meyer (1996); Roelofs, 1996a, 1996b). Theory and model are outlined in Fig. 1. The depicted example is one of naming a canoe. A block diagram of the process is presented in the left panel and a fragment of the computational model of the lexicon is presented in the right panel of the figure. For our present purposes a major feature of the theory is the rift that separates the initial and final stages of the process, the transition from conceptually driven access to the mental lexicon to phonological/articulatory shaping of the target word.

There are many ways to refer to an object. You can refer to a canoe with *a boat, a vessel, that thing*, etc. The perspective you take depends on the context of use (Clark, 1997; Levelt, 1996). The first step in picture naming is going from the visual image to a target lexical concept. In the laboratory, subjects are usually induced to produce basic-level terms—in the example, through the lexical concept ''canoe.'' In the computational model, WEAVER++ (Roelofs, 1992, 1996a, 1996b, 1997; Levelt et al., in press b), activation spreads via the semantic network to related concepts, such as ''ship,'' and this spread is measurable (Levelt et al. 1991). Activation also spreads one level down to the lemma *canoe*. The lemma is the syntactic word, i.e., the representation of the word's syntactic properties. *Canoe* is a noun; its Dutch equivalent has common gender, etc. WEAVER predicts for any shortest interval in time the probability that the target lemma gets selected, and hence the expected selection latency (Roelofs, 1992). Selecting the target lemma from among tens of thousands of other lexical entries completes the first, conceptually driven phase in picture naming.

During the second phase, the selected entry is given phonological-articulatory shape. Why do we postulate a rift in the system? First, the two

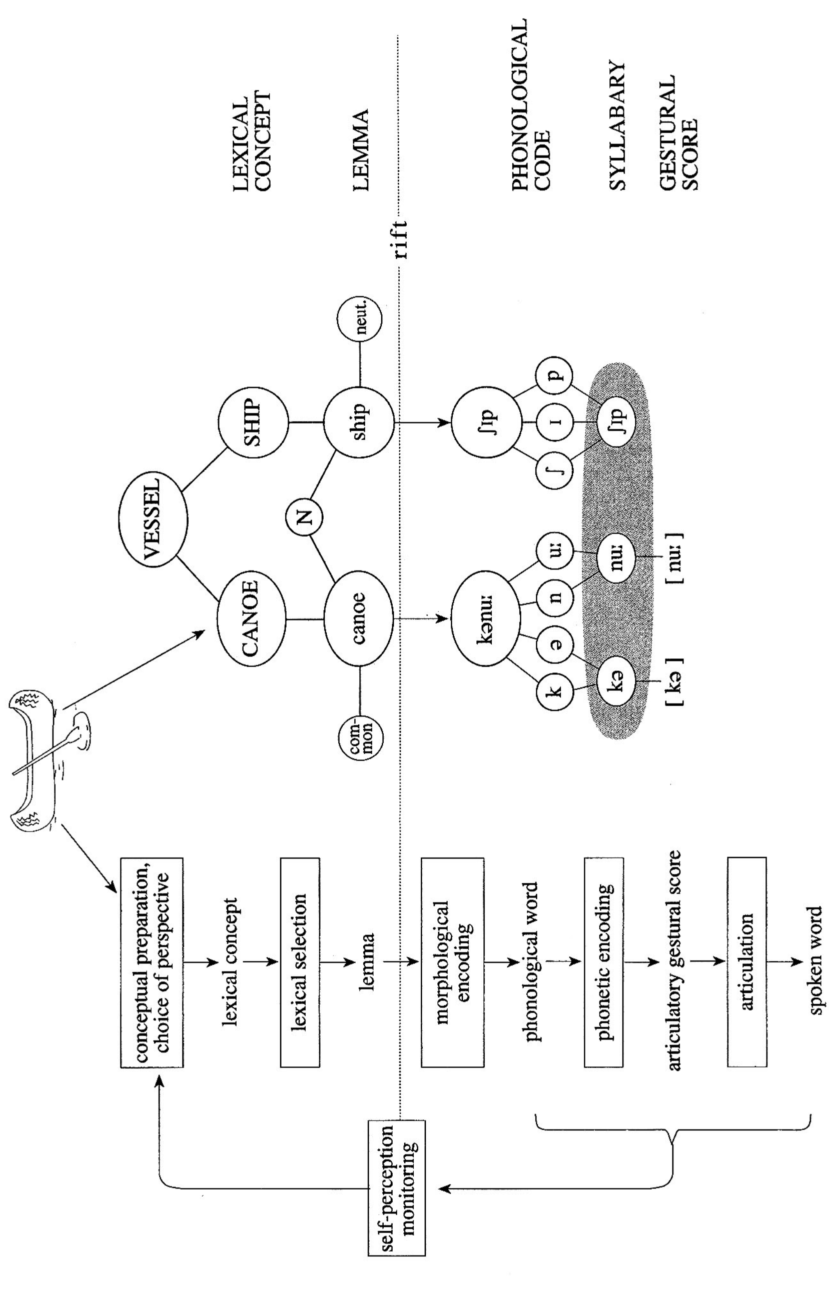

Fig. 1. Microgenetic model of object naming. Left panel: processing stages. Right panel: example fragment of lexical network.

kinds of process have thoroughly different aims. During the first phase, the speaker tries to zoom in on a single semantically appropriate lexical entry. The system is specialized in high-speed elimination of alternatives. And it is surprisingly robust at that; errors of lexical selection occur in the 1 in a 1000 range. During the second phase, the aim is to generate an articulatory program for the one selected item. Alternatives usually play a negligible role here. Rather, the major issue is to take the word's immediate phonological context into account. The syllabification of the word *understand*, for instance, differs in the two contexts "I understand" and "I understand it" (involving the syllables *-stand* and *-stan-*, respectively). Second, the ease of crossing the rift is word frequency dependent. You are faster naming a picture of a boat than one of a broom. Jescheniak and Levelt (1994) demonstrated that the locus of this word frequency effect is access to the phonological code. Though the word frequency effect causes only mild perturbations in the speed of lexical access, there can be a total block in accessing a word's phonological code, the well-known tip-of-the-tongue (TOT) phenomenon. In our theory, this sudden inability to retrieve the name of a familiar person, plant, or other referent represents trouble in crossing the rift. In other words, the TOT state results *after* selection of the lemma In *Speaking* (Levelt, 1989) I therefore predicted that in the TOT state the subject might have access to the word's syntax, in particular to the gender of an inaccessible noun (for gender-marking languages, such as Italian or Dutch). This prediction was recently tested and confirmed by Vigliocco, Antonini, and Garrett (1997) and by Caramazza and Miozzo (1997). Also, Badecker, Miozzo, and Zanuttini (1995) showed the same phenomenon for an Italian anomic patient, who could hardly name any picture but always knew the gender of the target name.

The computational model realizes the rift transition by activation spreading from the selected lemma. The phonological code accessed is now "spelled out," i.e., activation spreads to the morpheme's individual segments (such as /*k*/, /ə/, . . . , in the example). Also, the metrics of *canoe*, an iamb pattern, is spelled out. The major process of phonological encoding is a "left-to-right" process of syllabification. For *canoe*, the spelled-out segments are attached one by one to the iambic metrical frame, on the fly creating the two phonological syllables, /*k*ə/ and /nu:/, (cf. Levelt, 1992, for this proposal).[5]

During the next stage, phonetic encoding, these phonological syllables serve as addresses for the retrieval of "gestural scores" for [*k*ə] and [nu:].

[5] As has been recently discovered by Meyer and Roelofs (private communication) (see also Levelt et al., in press-a), there is no metrical spell-out for "default" metrical structures. For Dutch (like for English) word-initial stress counts as default.

These are abstract characterizations of the articulatory task to be performed (in the sense of Browman & Goldstein, 1992). After retrieval of a word's syllabic gestural scores, the articulatory system is ready to prepare and initiate the execution of the articulatory task. A central notion here is that of a mental syllabary. It is the repository of frequently used phonetic syllables. Although English, and Dutch for that matter, have more than 10,000 different syllables, cumulative statistics of syllable use show that no more than some 300 to 400 syllables are needed to produce 80% of connected speech. It is most unlikely that these highly overlearned syllabic patterns would not be available as ready-made gestural programs.

Finally, you can monitor your own speech, overt as well as internal. For reviews and recent experimental evidence, see Levelt (1989), Wheeldon and Levelt (1995), and Levelt et al. (in press a). So much for the microgenesis of spoken words. How can this theory help us to consider issues of ontogenesis, neurogenesis, and phylogenesis? Let us first turn to ontogenesis.

THE ONTOGENESIS OF SPOKEN WORDS

Although the word spurt starts halfway through the child's second year, the foundations of the enabling mechanism are laid during the first 12 months of life, when the child is an infant, i.e., speechless. During that first year of life, the systems at both sides of the rift go through a first phase of maturation, though totally independently. On the one hand, there is the maturation of a conceptual system. This is not the place to review the rich literature on conceptual growth during infancy, but by their first birthday, children have acquired basic concepts of place and time, of intention and causality. Also, they have acquired well-separated semantic domains of people, animals, and various kinds of objects, as well as action categories of different sorts. On the other hand, there is sudden maturation of a syllabary from the seventh month onward. The child begins with repetitive babbles of simple syllabic patterns, initially mostly consonant-vowel-patterns such as [gi-gi] or [da-da]. This repository of syllabic patterns functions in a highly autonomous audiomotor feedback loop. The syllabary is not only quickly extended over the final months of the first year, but it also gets tuned to the mother tongue's syllables (de Boysson-Bardies & Vihman, 1991; Elbers, 1982). But the most surprising fact is that this newly emerging articulatory-motor system has no systematic links to the conceptual system. This initial state is depicted in the left diagram of Fig. 2. By the end of the first year, there is a system of concepts (upper cloud) and an extensive articulatory-motor syllabary (bottom cloud) with no or hardly any link between them.

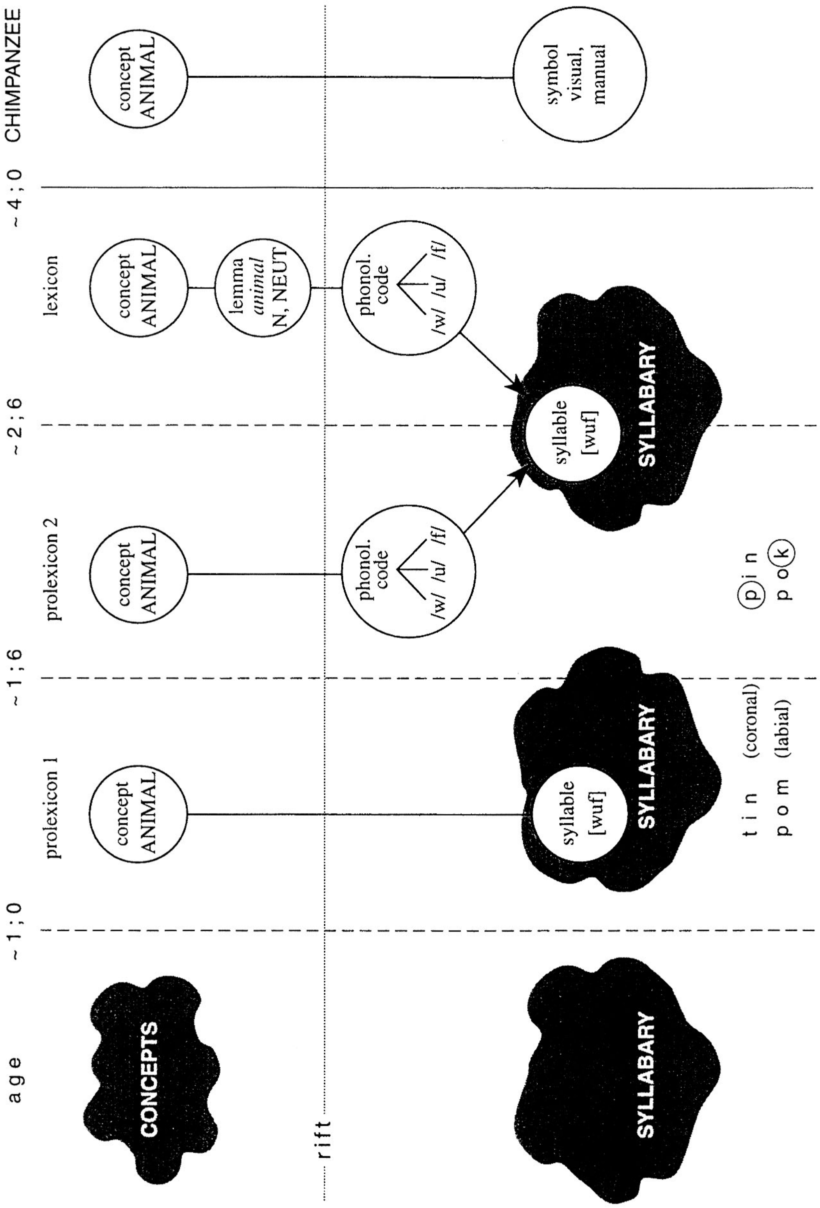

Fig. 2. Four ontogenetic stages in lexical representation, and lexical representation in (trained) chimpanzees.

However, around the first year of life the first few links are hesitantly established. The child singles out one syllable, or a combination of two, and systematically connects it with a conceptual referent. In Fig. 2's example, the syllable [*wuf*] is singled out to refer to domestic animals in the child's environment, such as all dogs and cats—see the second panel. Words like these are the child's first protowords. This protolexicon is built up with slowly increasing speed till halfway into the second year of life. Most parents loose track by then, because the protolexicon quickly expands beyond its by then about 50-item size. The problem is that the child looses track as well. Ever more syllables, and ever more similar syllables, have to be told apart in their referring functions; chaos is imminent. At this moment an intriguing process sets in, the phonologization of the lexicon. In her recent study of this process in 12 Dutch children, Clara Levelt (1994) discovered the course this takes. Initial protowords tend to have a uniform place of articulation. The child prefers words such as [*tin*], which is entirely coronal, or [*pom*], which is wholly labial. But then the child starts attending to the beginning of words. It begins to freely vary the articulation place of the word's onset, irrespective of the rest of the word. Next to [*tin*], for instance, a word such as [*pin*] can arise. Its onset is labial, but the rest of the word keeps being coronal. Usually a bit later, the child then begins to attend to the ends of words. A word's end may now receive a different place of articulation than the rest of the word. For Dutch children this is preferably a velar place. Hence, next to labial [*pom*], the child may start producing [*pok*] as a new protoword. And finally, the child begins to single out the syllable's nucleus for a free assignment of place. By allowing for these degrees of freedom, the child creates a generative phonological indexing system by which huge numbers of syllabic gestures can be kept apart in the syllabary. This is depicted in the third panel of Fig. 2. Phonologization is essentially complete a year after explosion of the protolexicon, i.e., by the age of 2;6.

What is still lacking by then is the lemma, the syntactic word. It is very easy for the child to sort actions versus objects. The child knows the similarity of *walking*, *jumping*, and *running* or the similarity of *dog*, *cat*, and *rabbit*. But it sees no similarity between *dog* and *leap*, both nouns that can be heads of a subject or object noun phrase (NP). A remarkable longitudinal study by Elbers and Wijnen (1992) of Dutch children showed that by the age of about 2;6 the child suddenly starts "investing" in function words. Before that time, function words, such as (in English translation) *in*, *from*, *of*, *that*, *if*, etc., were either not used at all, or just for referring to actions or objects of some kind. But suddenly, they become distinct from real content words such as *fix*, *horsie*, or *box*. They acquire their characteristic grammatical, syntactic function. Function words and inflections provide the sentence with phrase and clause structure. Around the age of 2;6 the child becomes utterly interested in building phrases and clauses. This syntactization of speech is an explosive development. For a typical child, for instance, the number of function words is less than one per sentence just before this development sets in. But then, within a month's time, between the ages of 2;6 and 2;7, it almost triples from 0.6 to 1.7. During the same month, the child suddenly starts producing very long sentences. This gain in length is entirely due to adding function words. But the child cannot immediately handle those new syntactic possibilities. Over a period of 3 months there is a marked increase in the child's disfluency rate, self-interruptions, self-repairs, repeats, hesitations. Only then does the system stabilize.

The final result of this syntactic explosion is the grammaticalization of the lexicon. To construct a sentence, the child must now know whether a word is a noun, a verb, an adjective, a preposition, etc., what argument structure and theta roles can go with phrases headed by these words, etc. That is precisely the lemma information in the lexicon. By the age of 4 to 5, the system is essentially there. As shown in the fourth panel of Fig. 2, the child's lexical item then consists of a lexical concept, a lemma, and a phonological code, just as is the case in the adult lexicon exemplified in Fig. 1.

THE NEUROGENESIS OF WORDS

How does the brain generate a word? Until recently, the main source of data relevant to this question came from open brain surgery. Since the pioneering work by Penfield and Roberts (1959) and Ojemann (1983), picture naming has become a standard test for localizing "language sites" in the patient's brain. Preceding resective surgery, and under local anaesthesia, an epileptic or glioma patient is subjected to a procedure called "stimulation mapping." During a picture-naming probe, some particular site in the wider perisylvian domain is electrically stimulated. This may induce a blockage of the naming response, an induced anomia. The neurosurgeon does better to avoid that area during resection. Probing 10 to 20 critical sites in a patient, an average of two or three such language sites are found. The maps published by Ojemann, Ojemann, Lettich, and Berger (1989) and by Haglund, Berger, Shamseldin, Lettich, and Ojemann (1994) show a wide distribution of sites over the left hemisphere, ranging from parietal to temporal, frontal, and prefrontal areas. The greatest concentration of sites is found in the superior temporal lobe. These are tremendously important data, but they don't tell us what functions the different sites fulfill. If only a single stage in the naming process (see the model of Fig. 1) becomes dysfunctional during naming, there will be no response. The patient may, under electrical stimulation of some site, not be able to activate a lexical concept, to select a lemma, or to access the word's phonological code or the relevant items in the syllabary; or there may be just a blockage of motor execution. How can this be sorted out? Or more generally, can we use a model of microgenesis to explore the neurogenesis of words?

Modern brain imaging makes this possible, at least in principle. By using a high temporal resolution imaging method, one should be able to trace the course of activation as the process rushes through the successive microgenetic stages. In a recent study, Levelt, Praamstra, Meyer, Helenius, and Salmelin (in press a) used magnetic encephalography to explore cerebral activation patterns during picture naming. The work was done on the Neuromag-122™ whole-head MEG apparatus of the Low Temperature Physics Laboratory in Helsinki.[6] Eight Dutch subjects participated in this experiment. Their magnetic response patterns over the 122 sensors were analyzed in terms of underlying dipole sources. The time windows for each of the processing stages in the model of Fig. 1 could be estimated from earlier work. This made it possible to determine which dipoles were active during each of the successive stages. Here is a summary of the results for dipole sources in the left hemisphere:

- *Visual processing and accessing the lexical concept*: occipital cortex
- *Lemma selection*: parietal, occipitoparietal and occipitotemporal areas
- *Phonological encoding*: Wernicke's area
- *Phonetic encoding and articulatory processing*: face motor area, also some temporal and parietal sites

This is a first, exploratory result. But it already shows how useful a well-tested, precise processing model can be in approaching issues of neurogenesis.

THE PHYLOGENESIS OF WORDS

This is a dark topic, and I have no intention of adding anything to the speculative literature on the first words of our ancestors in evolution. I only want to refer to two points made by David Premack in his George Miller Lecture, presented at the 1996 Cognitive Neuroscience Society meeting in San Francisco. The first was this: By now, it is well known that our closest evolutionary relatives, the chimpanzees, acquire a rich conceptual system,

[6] This work was supported by a grant from the Birch Foundation.

and one can train them to use symbols, such as plastic ''word'' chips to indicate concrete, but also pretty abstract, concepts. By training them to acquire words for *same* and *different*, those concepts can now be explicitly used to explore other conceptual abilities, such as recognizing semantic equivalence classes. In fact, chimpanzees can acquire amazing competence in semantic classifications. But Premack pointed out that they never succeed in acquiring a syntactic class as an equivalence class. Nounness or verbness, for instance, are not attainable as cognitive categories. To put this in terms of the microgenetic theory above, this means that chimpanzees never acquire lemmas.

It is an almost trivial fact that chimpanzees (or any primates other than humans) don't develop a syllabary either. They simply lack the articulatory apparatus that would, in principle, enable them to produce syllables. As a consequence, there can also not be any phonologicization of the lexicon. Slightly less trivial is the fact that no evidence indicates any kind of phonologicization when the chimpanzee acquires a gestural output system. In other words, chimpanzees do not develop discrete, generative systems of indexation for their gestural domain (like those in real sign languages).

The rightmost panel of Fig. 2 symbolizes this no-lemma, no phonological code nature of the ape's lexical items. The chimp's words are, basically, of the same nature as the child's protowords (displayed in the second panel); the chimpanzee's competence doesn't seem to get beyond that. In other words, phylogeny has provided only *homo sapiens* with symbols that are both syntacticized and phonologicized.

As a second point, Premack reminded us of another important difference between apes and man, namely the word *spurt*, which is uniquely human. Apes can acquire substantial vocabularies, but they still never go beyond a few hundred lexical items. Each new item must be trained; the ape is not ''sucking up'' words, as human children do. But it is precisely this rampant drive in young kids that make them receptive and active participants in a society of verbal comforting, argumentation, story telling, and instruction, i.e., in a culture.

CONCLUSION

The original, genetic perspective in psycholinguistics has not lost any of its attractiveness. It invites us to develop interdisciplinary theories that have the potential of linking the domains of microgenesis, ontogenesis, neurogenesis, and phylogenesis of language. The generation of words functioned as an example case, but just about any traditional subject in psycholinguistics can be approached in the same way. If we ultimately succeed, we will be in a position to answer the still crucial question of 19-century psycholinguistics: Where does language come from?

REFERENCES

Badecker, W., Miozzo, M., & Zanuttini, R. (1995). The two-stage model of lexical retrieval: Evidence from a case of anomia with selective preservation of grammatical gender. *Cognition, 57*, 193–216.

Bock, J. K., & Levelt, W. J. M. (1994). Language production. Grammatical encoding. In M. A. Gernsbacher (Ed.), *Handbook of psycholinguistics* (pp. 945–984). New York: Academic Press.

Browman, C. P., & Goldstein, L. (1992). Articuatory phonology: An overview. *Phonetica, 49*, 155–180.

Caramazza, A., & Miozzo, M. (1997). The relation between syntactic and phonological knowledge in lexical access: Evidence from the 'tip-of-the-tongue' phenomenon. *Cognition, 64*, 309–343.

Clark, E. V. (1997). Conceptual perspective and lexical choice in acquisition. *Cognition, 64*, 1–37.

De Boysson-Bardies, B., & Vihman, M. M. (1991). Adaptation to language: Evidence from babbling and first words in four languages. *Language, 67*, 297–318.

Elbers, L. (1982). Operating principles in repetitive babbling: A cognitive continuity approach. *Cognition, 12*, 45–63.

Elbers, L., & Wijnen, F. (1992). Effort, production skill, and language learning. In C. A. Ferguson, L. Menn, & C. Stoel-Gammon (Eds.), *Phonological development: Models, research, implications* (pp. 337–368). Timonium, MD: York Press.

Haglund, M. M., Berger, M. S., Shamseldin, M., Lettich, E., & Ojemann, G. A. (1994). Cortical localization of temporal lobe language sites in patients with gliomas. *Neurosurgery, 34*, 567–576.

Jescheniak, J. D., & Levelt, W. J. M. (1994). Word frequency effects in speech production: Retrieval of syntactic information and of phonological form. *Journal of Experimental Psychology: Language Memory & Cognition, 20*, 824–843.

Knoblauch, C. (1988). *Geschichte der psychologischen Sprachforschung in Deutschland von 1850 bis 1920*. Tübingen, Germany: Niemeyer.

Levelt, C. C. (1994). *The acquisition of place*. Leiden: Holland Institute of Generative Linguistics Publications.

Levelt, W. J. M. (1989). *Speaking: From intention to articulation*. Cambridge, MA: MIT Press.

Levelt, W. J. M. (1992). Accessing words in speech production: Stages, processes and representations. *Cognition, 42*, 1–22.

Levelt, W. J. M. (1996). Perspective taking and ellipsis in spatial descriptions. In P. Bloom, M. A. Peterson, L. Nadel, & M. F. Garrett (Eds.), *Language and space*. Cambridge, MA: MIT Press.

Levelt, W. J. M., Praamstra, P., Meyer, A. S., Helenius, P., & Salmelin, R. (in press a). An MEG study of picture naming. *Journal of Cognitive Neuroscience*.

Levelt, W. J. M., Roelofs, A., & Meyer, A. S. (in press b). A theory of lexical access in speech production. *Behavioral and Brain Sciences*.

Levelt, W. J. M., Schriefers, H., Vorberg, D., Meyer, A. S., Pechmann, Th. & Havinga, J. (1991). The time course of lexical access in speech production: A study of picture naming. *Psychological Review, 98*, 122–142.

Meyer, A. S. (1996). Lexical access in phrase and sentence production: Results from picture-word interference experiments. *Journal of Memory and Language, 35*, 477–496.

Ojemann, G. A. (1983). Brain organization for language from the perspective of electrical stimulation mapping. *Behavioral and Brain Sciences, 6*, 189–206.

Ojemann, G. A., Ojemann, J., Lettich, E., & Berger, M. (1989). Cortical language localization in left, dominant hemisphere. *Journal of Neurosurgery, 71*, 316–326.

Osgood, C. E., & Sebeok, T. A. (Eds.) (1965). *Psycholinguistics. A survey of theory and research problems.* Bloomington: Indiana University Press.

Penfield, W., & Roberts, L. (1959). *Speech and brain mechanisms.* Princeton, NJ: Princeton University Press.

Roelofs, A. (1992). A spreading-activation theory of lemma retrieval in speaking. *Cognition, 42*, 107–142.

Roelofs, A. (1997). The WEAVER model of word-form encoding in speech production. *Cognition, 64*, 249–284.

Roelofs, A. (1996a). Serial order in planning the production of successive morphemes of a word. *Journal of Memory and Language, 35*, 854–876.

Roelofs, A. (1996b). Morpheme frequency in speech production: Testing WEAVER. In G. E. Booij & J. van Marle (Eds.), *Yearbook of morphology* (pp. 135–154). Amsterdam, The Netherlands: Kluwer.

Steinthal, H. (1855). Grammatik, Logik und Psychologie, ihre Prinzipien und ihr Verhältnis zueinander. Berlin.

Vigliocco, G., Antonini, T., & Garrett, M. F. (1997). Grammatical gender is on the tip of Italian tongues. *Psychological Science, 8*, 314–317.

Wheeldon, L. R., & Levelt, W. J. M. (1995). Monitoring the time course of phonological encoding. *Journal of Memory and Language, 34*, 311–334.

Wundt, W. (1900). *Die Spache* (2 vols.). Leipzig, Germany: Engelman.