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Parallel or serial activation of word forms in speech production? Neurolinguistic evidence from an aphasic patient

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Abstract

We report the oral picture naming performance of the German aphasic MW who presented with frequent meaning related word substitutions (e.g. tiger ⇒ lion) and word finding blockings (omissions) while his phonological capacities at the single word level were nearly preserved. Targets were controlled for their 'semantic competitiveness', that is, whether there exist closely meaning related lexical competitors or not. Semantic errors were far more numerous with the highly competitive targets than with the low competitive ones. However, omissions were more frequent with the low competitive items so that the sum of the semantic errors and of the omissions was comparable in both conditions. This inverse and compensatory relationship suggests that both error types are not mutually independent. The found pattern is at odds with serial psycholinguistic theories which locate word selection (and misselection) and word form access (and blockings) at different and serially connected stages of word production but supports theories which allow for a parallel architecture in lexical activation and selection involving the word form level.

Keywords: Aphasia; Neurolinguistics; Naming; Semantic paraphasia; Word production; Parallel activation

Current theories of lexicalisation in speech production can be classified into approaches with serial or parallel lexical form access [11]. In the former [5,8], lexical access proceeds from a stage of conceptually-driven syntactic encoding (lemma level), where the target word is selected from a set of parallel activated meaning related lexical candidates, to a second stage of retrieving and encoding the phonological form of the selected word only (word form level). According to this serial approach, semantic word selection errors arise during the first stage of lexicalisation, while word-finding blockings are traced back to difficulties in the second stage. In serial two-step models, both levels are independent and discrete in time thus allowing, e.g. for undisturbed word access in cases of wrongly selected lemmas.

Theories postulating parallel access of lexical form assume that more than one lexical candidate can reach the word form level and that the word form level is involved in lexical selection. According to this approach, blockings of word form retrieval can trigger the production of a semantically co activated and more accessible word forms. Thus, disturbances at the word-form level can give rise to both semantic errors and word finding blockings and both symptoms are not independent [3,9]. A related claim is made by models postulating cascading (time overlap between earlier and later stages) or interactive (feedback) activation in lexical processing [4,6].

However, under the impression of recent experimental evidence [7,10] from naming near-synonyms as targets (e.g. sofa/couch), the strict serial position has been partially modified. Now, it is assumed that multiple word forms per targeted object can be active in parallel because in certain communicative situations (e.g. naming objects with several appropriate names) more than one lemma can be selected [8]. But still, lexical selection is viewed as a function of the lemma level only.

In the following, a picture naming study of the aphasic patient MW is reported. We investigated the distribution of MW's semantic errors and word-finding blockings under different conditions of lexical selection (controlled by the targets' semantic competitiveness). The study is based on the methodological principles of single case studies in

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cognitive neuropsychology [2] including: (a) that aphasic language processing can be investigated within the framework of psycholinguistic models; and (b) that the relationship between normal and impaired performance can be made 'transparent' by appropriate analysis.

At the time of investigation, MW was a 58-year-old German speaking man who suffered from chronic aphasia after an infarction in the territory of supply of the left middle cerebral artery 13 years before. His spontaneous speech almost exclusively consisted of recurring utterances ('ja weiβt du was' – 'yes (do) you know what'). Repetition of words and non-lexical phonemic strings was well preserved (up to three syllables). Oral naming was partially preserved and only minimally affected by phonological errors. Therefore, the lexical properties of his naming responses could reliably be analysed.

MW's working memory capacity was severely compromised. Sequences of three and four digits could only rarely be repeated correctly (three/40) in contrast to 4-syllabic nominal compounds (56/60) or pseudocompounds (46/60). In an object association task (matching one object picture to one of two others based on semantic knowledge – 'pyramids and palm trees'), MW was faultless. In an auditory word-picture matching task with semantic distractors, he made 16/80 errors. Word-picture matching with phonologically similar distractors yielded only five/150 errors. In an auditory lexical decision task, he performed well with three/80 errors. In summary, MW's problems in single word processing were more severe at the lexical-semantic level (see below for his semantic errors in picture naming), while his phonological capacities were relatively intact.

The basic assumptions underlying our investigation were: (a) that some target words have closer semantic competitors than others; and (b) that targets (e.g. Gabel (fork)) with close competitors (e.g. (Löffel (spoon) or Messer (knife)) attract more semantic errors than those with low competition (e.g. Brille (spectacles/glasses)).

Three picture naming experiments were made in succession with three different sets of target nouns (A–C). Set A consisted of 23 high- and 23 low-competitive items, set B contained 26 each, and set C 20 each. Targets were controlled for their semantic competitiveness by having 20 students of Linguistics (Freiburg University) rate each item using a 3-point scale (1. hardly any/2. some/3. many competitors). The results in medians were (in the given order of the scale) for the highly competitive items 2/9/9 for Set A, 2/8.5/7 for Set B, and 2/9/9 for Set B and for the low competitive items 10/8/2, 10.5/8/1.5, and 12.5/6.5/1, respectively. In each of the three naming experiments the respective set was repeatedly presented to MW with at least 1 week in between sessions (A and B seven times each, C three times). The high- and low-competitive subsets were matched for frequency using CELEX [1]. All targets were mono- or bisyllabic. Compounds were excluded. Items of all sets were presented in pseudorandom order. In cases of no or incorrect responses, the first sound or syllable of the target was orally presented. If this cue failed, MW was given the correct name for repetition. Only first responses were scored.

Fig. 1 gives the results of MW's naming performance for all 17 trials. MW's responses were classified by using the following categories: correct responses, omissions, semantically related responses (semantic paraphasias), and other responses (other). The last category was the smallest and consisted of heterogeneous responses (form related or unrelated words and one fragment. In all three experiments, the number of semantic errors and omissions varied in dependency of the targets' semantic competitiveness (overall 31.5 versus 11.9% semantic errors and 23.3 versus 45.2% omissions). Statistical analysis of combined first trials reveals significant differences between the high- and low-competition conditions for number of omissions ($Chi^2 = 9{,}49$; $P < 0.01$) and semantic paraphasias ($Chi^2 = 9{,}58$; $P < 0.01$). The sum of both error groups is remarkably similar in both conditions (overall, 54.8 versus 57.1%).

The introduced variable of 'semantic competitiveness' was found to be a potent predictor for MW's response pattern in naming object pictures. In fact, semantic errors clustered around the highly competitive items stemming from dense semantic categories while the low competitive targets largely hindered the patient to make any meaning related errors. By either provoking or suppressing MW's semantic substitutions, we were able to inspect his word finding blockings for their potential co-variation with his semantic errors.

What we could observe was a clearly inversely related distribution of semantic errors and omissions under both conditions of competitiveness: Many semantic errors and few omissions with the high-competitive items and the opposite with the low-competitive targets, while the sum of both error types was quite comparable between conditions.

This pattern is not expected by the serial two-step account of lexicalisation. Within this architecture, both error events are assumed to be independent and discrete in time. According to this model, a decrease of semantic word selection errors (lemma level) should positively influence the number of correct responses and should not lead to an increase of omissions (in the size of the reduction of semantic errors).

Instead, MW's pattern clearly supports the parallel account of lexicalisation. Models assuming parallel activation of meaning related lexical forms allow for semantic errors secondary to blocked word form access (see, e.g. the Logogen Model [9] or the Independent Network Model [3]). However, our results do also concur with interactive two-step models which assume parallel activation of meaning related lexical items and which postulate lexical selection involving word form information, see, e.g. ref. [4].

One could object that a restarting device after failed word form access could make the data compatible with the serial account [12], that is, the speaker may be forced to start anew and to select a different lexical candidate (lemma) and then

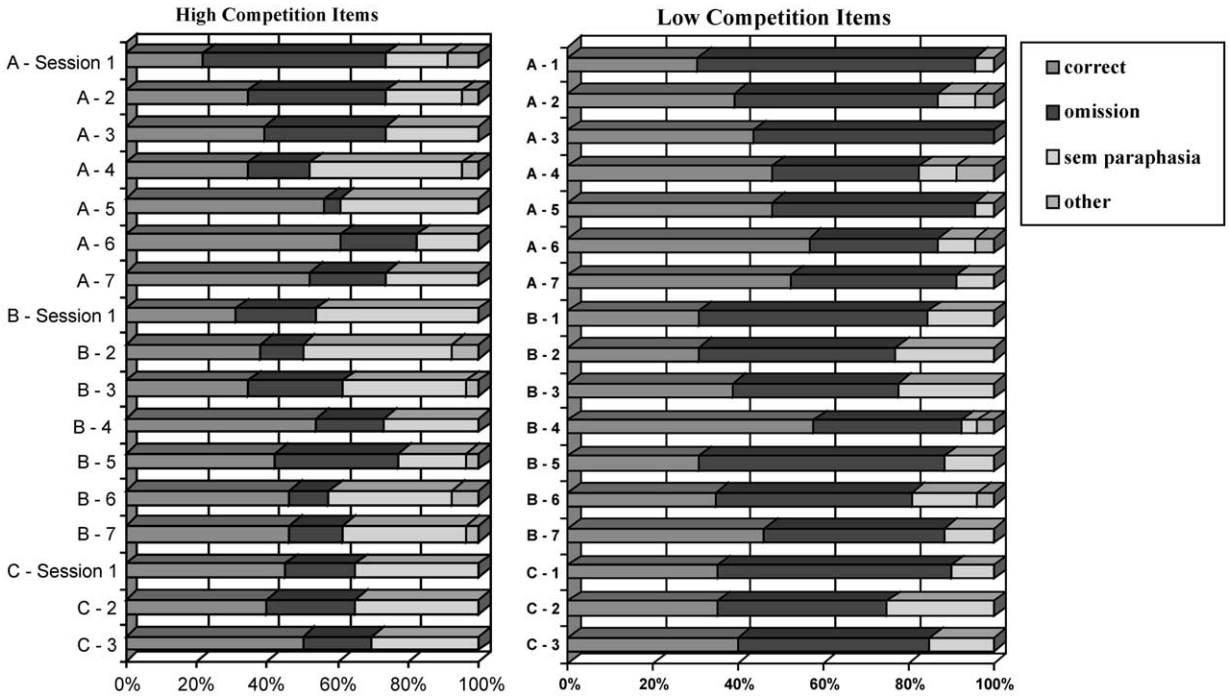

Fig. 1. Naming results of MW: percentage of response types with high- versus low competition items. Results of seven sessions with Set A; seven sessions with Set B; and three sessions with Set C (see text).

to proceed to the word form level a second time. But again, since word form access is an independent step, it may fail, as the first attempt, thus leaving the serial model with the difficulty to account for the inverse and compensatory relationship between semantic errors and omissions between both conditions of competitiveness.

A further objection could be that MW suffers from permanent loss of lemma representations (or consistent access problems) which could be compensated by semantic substitutions of co activated lemmas, but less so in case of low competitive items. However, MW did not exhibit a pattern of consistent unavailability of targets. In sets A and B, which were repeated seven times each, only one item lead to consistent omissions over all seven sessions.

Our aphasiological data strongly suggest that word form access is crucially involved in lexical (mis-)selection. However, we cannot decide whether lexical selection is a feature of the word form level itself [3,9] or whether lexical selection is a feature of a higher level (e.g. lemma level) within an interactive architecture where word form encoding can begin before lexical selection is completed and lower levels are allowed to influence higher ones [4].

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