Stem-, Spraak- en Taalpathologie
2001, Vol. 10, No. 4, pp. 283-287

32.8310/01/1004-283

Task related paralexias in number reading

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We present a patient, GR, producing verbal paralexias in reading Arabic numerals. The error rate of his paralexias depended on the kind of task, number reading was embedded in. Thus, he made significantly more errors in reading division problems he had to solve afterwards than in reading the same division problems with the solution already given. Despite paralexic reading of the problem, GR's oral production of the solution was mostly correct. This pattern can be added to those found by Girelli & Delazer (1999) and Delazer & Bartha (2001). It will be discussed in the light of current models of number processing.

Introduction

Given the frequent co-occurrence of aphasia and acalculia, the presence of paraphasias and paralexias may often be misleading in the assessment of calculation abilities as shown, for example, by Benson and Denckla (1969). One of their patients (case 1), for instance, produced paralexic errors in number reading but his number comprehension abilities were preserved, as demonstrated by matching number words to Arabic numerals or tokens. In calculation, he offered wrong answers in both written and oral output, but was unimpaired in pointing to the correct answer on a multiple choice list (for "4 + 5" he said "eight", wrote "5" and chose "9"). After this influential study, output modalities like multiple choice tests, writing Arabic numerals or acting out with tokens have often been used to complete the calculation diagnosis or even to replace oral production to minimize interference with language disturbances. The precise nature of the relationship between paraphasic production and calculation has, however, only rarely been investigated.

Cipolotti (1995) and Cipolotti and Butterworth (1995) proposed a model of number processing which added a distinction between semantic and non-semantic processing to the model of McCloskey and colleagues (McCloskey et al., 1985, McCloskey, 1992). This expanded version of the model allowed to explain the pattern found in their patient SAM, who showed severe difficulties in number transcoding tasks (reading as well as writing) despite good number recognition and understanding. Most strikingly, SAM was well able to perform oral and written calculation.

Just recently, Girelli and Delazer (1999) and Delazer and Bartha (2001) described single cases with three different patterns of how errors in reading the tasks can influence the production of results: Patient BP always relied on the visual input, despite

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his frequent verbal paraphasias in reading the problem. His verbal answers were correct in only 50% of the cases. He did, however, much better (95% correct) in written responses, given immediately after the verbal ones. This near ceiling performance in written output proves that BP ignored his own paralexic reading of the problems. In addition to this, the kind of errors showed no systematic relationship to the misread problems. A completely different pattern was shown by patient GS. He misread 16% of the operations, but for all of them he retrieved the correct answer to the verbally produced fact, thus showing a complete reliance on his verbal production and ignoring the visual input. Patient FS, finally, was equally likely to rely on or to disregard the misread problem in retrieving the answer.

We present a patient, GR, whose reading performance was outstanding for two reasons: 1) paralexias were influenced by the type of task presented - the patient being better in pure reading tasks than in tasks requiring semantic elaboration or increasing processing load by other means, 2) paralexic errors in reading calculation tasks did not influence the patient in verbally producing the correct result.

Case description

GR, a 64 years old former accountant, suffered a CVA in the region of the left middle cerebral artery in October 2000. His main cognitive symptoms included a reduced verbal (3), but spared visual memory span (Corsi Block Tapping 5), and paraphasias as well as paralexias. His language profile according to the Aachen Aphasia Test is shown in table 1:

Test	October2000	January2001
Token Test (age corrected errors)	3/50	0/50
Repetition	122/150	122/150
Reading	24/30	30/30
Spelling by Tokens + Writing	30/60	57/60
Naming	111/120	119/120
Understanding	112/120	118/120

Table 1. GR's results in the Aachener Aphasie Test

Methods

The patient read different sets of numbers between January and March 2001:
Set A: reading and performing calculation tasks (addition, subtraction, multiplication and 2 x division [N=36, 46, 36, 46 respectively] containing the same operands);
Set B: reading the same division tasks with solution already given (2x[N=46]);
Set C: reading isolated numbers (containing all operands and solutions of sets A and B [N=90]);

Set D: reading numbers and parity judgement (N=90);
Set E: reading coloured numbers and naming the colour of the number presented before ("colour interference") (N=90);
Set F: number comparison, F1: reading the number and comparing it with the number previously read, F2: reading the number and comparing the one previously read with it;

Set A (the division tasks only), B and C were presented in an A, B, C, C, B, A paradigm within one session.
Set C, D, E and F contained the same numerals, up to 4 digits long, in randomised order.

Results

GR made several paralexic errors when reading numbers that were embedded in additional tasks. This was true for calculation (22% errors in Set A [division]) as well as for parity judgement (14% in Set D) and colour interference naming (17% in Set E). However, significantly less (3% in Set C) or no paralexias occurred when the same numbers were presented in isolation or with the solution already given (A vs. B: McNemar test, p = 0.039; D vs. C: Pearson's (2 = 7.386, p = .007; C vs. E: (2 = 5.765, p = .016). There was no significant difference (McNemar test, p = 0.227) between performance in reading isolated numbers and reading calculation tasks with the solution given, despite the latter being worse (12% in Set B). Comparing numbers in one direction resulted in a tendency to produce more reading errors than comparison in the other direction, depending on the working memory load implied (F2: 10%, F2: 2% Pearson's (2 = 1.378, p = 0.24, n.s.).

In a comparison of the four fundamental operations of arithmetic no significant difference was found (McNemar test, all p > .42), although division seemed to be most error-prone.

Reading errors for numbers in isolation almost exclusively affected the first digit of 4-digit-numbers. In the majority of all cases, errors could be classified as perseverations of some part of a number previously read (For 7 – 1 = and 2 – 2 = he read "7 – 1 = 6, 7 – 2 = 0", for 45 : 5 and 32 : 4 he read "45 : 5 = 9, 35 : 4 = 8). In reading the first operand of calculation problems, the patient sometimes also anticipated the second operand or parts of it or even the result or parts of it (For 360 – 18 = he read "180 – 18 = 342", for 14 – 2 he read "14 – 12 = 11", for 63 : 7 = he read "63 : 9 = 7 // 9").

Despite the presence of paralexic errors, calculations and judgement tasks were performed correctly in the overwhelming majority of cases. The patient read, for example, *8:1* as "4:1" but offered the correct oral response "8". This was also true for paralexias in multiplication (For 7 x 9 he read "9 x 9 = 63", for 9 x 3 "6 x 3 = 27").

Discussion

The pattern of performance shown by GR, i.e. correct oral solution of calculation tasks despite paralexic reading, adds one new pattern to the findings of Girelli and Delazer (1999) and Delazer and Bartha (2001).

It is difficult, however, to integrate the present data into most of the current speech production models, which are primarily concerned with language specific processing and cannot account for task specific results depending on contextual demands.

The distinction between semantic and asemantic number-processing alone (Cipolotti, 1995; Cipolotti & Butterworth, 1995) fails to account for the observed pattern as well. GR's performance does not depend on the degree of semantic processing involved. He is worse in tasks which require semantic elaboration - as shown by number comparison reading vs. reading isolated numbers - but this is also the case in tasks which require any (non-semantic) additional processing load. The purely semantic aspect is the same in both types of number comparison and cannot explain the one being more difficult than the other (F 2 vs. F 1).

The finding of correct results in multiplication despite paralexic reading of the problem is at odds with models postulating that arithmetic facts (at least in simple multiplication) are retrieved exclusively by verbal associations (e.g. Dehaene & Cohen, 1995). Such models do not predict the behaviour of patients like BP (Girelli & Delazer, 1999) or GR, who ignore their own verbal production as input, completely relying on visual stimuli. This aspect of the presented data can, on the other hand, be accounted for by the models of McCloskey (1992, McCloskey et al., 1985) and Cipolotti (1995, Cipolotti & Butterworth, 1995), which do not claim verbal fact retrieval and by the model of Noël and Seron (1993, 95), which allows for individual preferences in the format mediating fact retrieval.

Thus, further investigations are needed to shed light onto the interaction between language-specific processes, mnemonic and executive functions required in operations like calculation or number evaluation and reading.

Samenvatting

In dit artikel presenteren wij een patiënt, G.R., die bij het lezen van cijfers verbale paralexieën produceert. Het aantal leesfouten was afhankelijk van de aard van de taak waarbij de cijfers gelezen werden.. Zo maakte hij significant meer fouten bij het lezen van deelsommen als hij ze vervolgens moest oplossen dan bij het lezen van dezelfde deelsommen als hij het antwoord al wist. Ook al kwamen bij het lezen van het probleem paralexieën voor, bij mondelinge productie was . de oplossing meestal correct. Dit patroon past bij de bevindingen van Gireli and Delazer (1999) en Delazer and Bertha (2001). De resultaten worden besproken in het licht van gangbare modellen voor de verwerking van cijfers.

Notes

This work was supported by grant HPRN-CT-2000-00076 by the European Community..

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