

Working memory and semantic involvement in sentence processing: A case of pure progressive amnesia

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Abstract

ED, a 83-year-old woman, meets the criteria of pure progressive amnesia, with gradual impairment of episodic and autobiographical memory, sparing of semantic processing and strong working memory (WM) deficit. The dissociation between disturbed WM and spared semantic processing permitted testing the role of WM in processing anaphors like pronouns or repeated names. Results showed a globally normal anaphoric behavior in two experiments requiring anaphoric processing in sentence production and comprehension. We suggest that preserved semantic processing in ED would have compensated for working memory deficit in anaphoric processing.

Keywords: Pure progressive amnesia; Anaphors; Language; Production; Comprehension

1. Introduction

The rare patients presenting with pure progressive amnesia exhibit severe episodic memory deficit with occasional working memory deficit (Bertolucci, Siviero, Bueno, Okamoto, & Santos, 2004; Didic, Ali Cherif, Gambarelli, Poncet, & Boudouresques, 1998). Semantic memory, autobiographical memory and language are preserved (Joubert, Barbeau, Walter, Ceccaldi, & Poncet, 2003). We studied a patient, ED, diagnosed as pure progressive amnesia, who after 6 years of evolution, showed mainly important episodic and working memory deficits. We tested ED's ability to produce and interpret anaphoric forms. Anaphors like pronouns *he* or *she* are essential as they indicate that a constituent previously introduced in discourse, known as the antecedent,

is currently being referred to. Anaphor processing would depend on working memory (Garrod, Freudenthal, & Boyle, 1994). Almor, Kempler, MacDonald, Andersen, and Tyler (1999) showed that AD patients had difficulties for processing pronouns, whereas they were aided by repeated nouns which provide more explicit cues to accessing the referent in working memory. An important discourse feature for anaphoric processing, not taken into account in Almor et al.'s study, concerns the semantic representation of the discourse in which the discourse focus is more prominent and has a higher semantic weight than other candidates (Garrod et al., 1994). Recent evidence suggests that depth of semantic processing is influenced by focussing (Sturt, Sanford, Stewart, & Dawydiak, 2004). Once being at the centre of attention, the focus becomes readily accessible to pronominal anaphoric reference (Garrod et al., 1994). Working memory (WM) deficit coexisting with spared semantic processing in ED offers the possibility to study the influence of WM in anaphoric processing.

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2. Case history

ED, an 83-year-old right-handed woman, was referred to the Department of Neurology for memory impairment. At this time, neuropsychological examination was normal. Six years later, at the time of the study, MMSE score was 24/30 and ED met the criteria of pure progressive amnesia. However, she was independent in daily life and able to pursue her hobbies such as crosswords.

2.1. Memory

Memory Quotient was 86 on Wechsler Memory Scale. Digit spans were three forward and two backward. Verbal episodic memory was disturbed (8/16 on immediate free recall, 0/16 on recall 3; 2/16 on delayed recall; 11/16 on recognition). Working memory was very poor (word span: 3; letter span: 2.5; month ordering: 3.5; reading and listening spans: 2 and 3). Autobiographical memory was preserved for past periods and poor for recent episodes.

2.2. Semantic processing and language

ED's semantic processing was well preserved (25/30 on the Pyramids and Palm Trees test, 25/44 on the Binois-Pichot vocabulary test (VIQ \approx 106), 10/14 on the WAIS similarity subtest). Performance was good on semantic and phonemic fluency tests (26 and 24 hits, respectively) with several repetitions (15). No word-finding difficulties were noted (77/80 on the DO 80). Reading and text comprehension were normal.

A control group included 12 right-handed age-matched women (mean MMS: 29 ± 1.2).

3. Experiment 1: production task

3.1. Materials and procedure

Forty two-sentence texts with two different gender characters were constructed. The focused character (Entity 1) occurred in subject position. The less-focused character (Entity 2) occurred in oblique object position as shown by the following example: *'Les voyageurs pour Paris attendaient sur le quai./The travellers for Paris were waiting on the platform/Joseph^{Entity 1} embrassait la main de Judith^{Entity 2} en fermant les yeux./Joseph^{Entity 1} kissed Judith's^{Entity 2} hand while closing his eyes/.* The participants were instructed to read aloud each text and to tell a semantically suitable continuation sentence mentioning at least one character. We calculated for each subject the number of anaphors referring to Entities 1, 2 and 1 + 2. We classified the first two anaphor types (to Entities 1 and 2) in pronouns or repeated names since anaphors referring to Entities 1 + 2 consisted in a single form, i.e. a masculine plural pronoun (ils – "they"). We compared the patient's performance to the control subjects by using Z-scores with results expressed in standard devia-

tions (S.D.). Values of S.D. \geq or ≤ 2.201 mark an abnormal score. Three judges estimated by 'Yes' or 'No' judgments, the relevance of ED's continuations according to the prior context in terms of "appropriate use of anaphors" and global semantic coherence.

3.2. Results

All ED's continuations were judged coherent. ED showed good inferential capacities, as shown by the continuation for the text mentioned above: *"Il était amoureux, il avait du chagrin!/He was in love, he was sad!/"*.

The number of references to Entities 1, 2 and 1 + 2 in the control group was $20.25/40 \pm 4.4$, $6.9/40 \pm 2.9$ and 12.5 ± 5.7 , respectively. The number of references to Entity 1 in ED was 30/40 that corresponds to +2.2 S.D.; for Entity 2, performance was 9/40, i.e. +0.7 S.D. and for Entities 1 + 2, performance was 1/40, i.e. -2 S.D.

Control subjects did not favor a specific anaphoric form for Entity 1 (pronouns $10.6/20.25 \pm 9.1$, repeated names $9.6/20.25 \pm 7.9$); by contrast, they referred to Entity 2 significantly (t -test, $p < 0.003$) more by a repeated name ($5.7/6.9 \pm 2.9$) than by a pronoun ($1.2/6.9 \pm 2$).

For Entity 1, ED produced 30/30 pronouns and 0 repeated names. Despite this contrast, Z-scores were in the normal range (pronouns: +1.19 S.D.; repeated names: -1.19 S.D.). For Entity 2, ED overused pronouns (8/9, +3.6 S.D.) and underused repeated names (1/9, -3.8 S.D.).

4. Experiment 2: comprehension task

4.1. Materials and procedure

Forty texts included three sentences and a 'Yes/No' question, the two first sentences being the same as in Experiment 1. The third sentence, i.e. the target sentence, referred to the focused or the less focused entity via a pronoun or a repeated name, yielding four conditions (Table 1). 'Yes/No' questions probed target sentence comprehension. For the control group, four lists of 40 texts (10 by condition) and 40 filler texts were created such that each text appeared in each condition but each participant saw one version of each text. ED read each text in the four conditions and the 40 filler texts in eight separate sessions.

Subjects had to read texts at normal speed and answer questions as accurately as possible. Stimuli were presented on a computer screen and data were collected in a Superlab script. Each trial (40 texts) included self-paced reading of the two first sentences, space bar pressing, target sentence presentation, space bar pressing, 'Yes/No' question display until subjects responded. The time of presentation of the target sentence (from the onset of presentation to the following space bar press) and number of errors were recorded. The text order was randomized and counterbalanced between sessions. We compared ED's performance to the control subjects by using

Table 1

Example of an experimental text

Sentence 1	Les embouteillages du soir ralentissaient la circulation (<i>The evening bottlenecks were slowing the traffic down</i>)
Sentence 2 (Entity 1) vs. Sentence 2 (Entity 2)	<i>Isidore</i> guettait le retour de Laure en préparant le repas/ <i>(Isidore was expecting Laure's return while preparing the meal)</i> vs. Laure guettait le retour d' <i>Isidore</i> en préparant le repas/ <i>(Laure was expecting Isidore's return while preparing the meal)</i>
Sentence 3 (target sentence)	
Pronoun	Au bout d'un moment, il se mit à rouspéter/ <i>(After a while, he got grumbling)</i>
Repeated name	Au bout d'un moment, Isidore se mit à rouspéter/ <i>(After a while, Isidore got grumbling)</i>
'No' question	Est-ce que la femme s'est mise à rouspéter?/ <i>(Did the woman get grumbling?)</i>

Note: The antecedent-entity (Entity 1 or 2) is in italic for expository purposes. The slash indicates the text presentation on the screen. The target sentence (TS) and the question were presented separately on the screen.

Table 2

Reading times of the target sentence and errors for the questions in Experiment 2

	Entity 1/pronouns	Z-score for ED	Entity 1/repeated names	Z-score for ED	Entity 2/pronouns	Z-score for ED	Entity 2/repeated names	Z-score for ED
ED								
Mean RT (S.D.)	100.1 (23.6)	1.69	103.8 (25.7)	1.66	111 (32.2)	1.67	112.4 (36)	2.34
Error	10%	1.36	0%	-0.8	20%	1.66	12.5%	1
Controls ($n = 12$)								
Mean RT (S.D.)	68.4 (18.7)		74.3 (17.7)		80 (18.5)		73.9 (16.4)	
Error (S.D.)	3.3% (4.9)		4.1% (4.1)		5% (9)		5.8% (6.7)	

Note: Reading times are expressed in milliseconds per character; Z-scores in bold are abnormal.

Z-scores with results expressed in standard deviations. Values of $SD \geq$ or ≤ 2.201 mark an abnormal score.

4.2. Results

Although ED's reading times were prolonged (Table 2), Z-scores were in the normal range for sentences with pronoun referring to Entity 1, repeated name referring to Entity 1, and pronoun referring to Entity 2. By contrast, for repeated name referring to Entity 2, Z-score was abnormally high. ED did not produce more errors than control subjects, whatever the condition. No difference was noted between 'Yes' questions and 'No' questions.

5. Discussion

ED met the criteria of pure progressive amnesia (Lucchelli, De Renzi, Perani, & Fazio, 1994), with gradual impairment of episodic and autobiographical memory contrasting with sparing of semantic processing. ED exhibited moreover strong WM deficit, a deficit not constant in these patients (Joubert et al., 2003). Disturbed WM coexisting with spared semantic processing permitted testing the role of WM in anaphoric processing.

In the production task, ED used anaphors coherently and favored significantly more the retrieval of the focused entity than control subjects, a finding congruent with the discourse topic preservation reported in AD patients (Garcia & Joannette, 1997). This hypersensitivity to discourse focus may be interpreted in ED as a parsimonious use of the remaining

WM resources, an interpretation in line with Sanford and Garrod's focus theory (1981). A complementary explanation is that the focused entity would benefit from an in-depth semantic processing (Sturt et al., 2004), which is intact in ED. When considering anaphor types, ED did not differ from the control group for the focused entity whereas, for the less focused entity, ED showed a reverse anaphoric behavior relative to control subjects (overused pronouns and underused repeated names). The preserved semantic processing of ED might account for this unexpected pattern as she had appropriate representation of the two characters, with good inferential abilities. When referring to the less focused entity, ED might put it temporarily on focus position as she probably had difficulties in maintaining differently focused entities in WM. This "focus status" favors pronouns and not repeated names.

Performance on the comprehension task was mainly normal for questions (even for 'No' questions) as well as for reading times. Abnormally longer reading times were only found in the repeated name/Entity 2 condition. These results challenge Almor et al.'s (1999) views, which underlined general facilitation for repeated anaphors in AD patients. Although difficult to interpret, the penalty for repeated name/Entity 2 might be explained in line with Sanford and Garrod's theory, which postulates an indirect access to the antecedent for a repeated name, which is first considered as a new semantically loaded token. The delay observed in ED could be due to this semantic step.

In conclusion, despite her profound WM deficit, ED shows an appropriate anaphoric behavior. We suggest that spared semantic processing might overcome WM limitations for anaphoric processing in pure progressive amnesia.

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