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Short-term and working memory impairments in aphasia

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ABSTRACT

The aim of the present study is to investigate short-term memory and working memory deficits in aphasics in relation to the severity of their language impairment. Fifty-eight aphasic patients participated in this study. Based on language assessment, an aphasia score was calculated for each patient. Memory was assessed in two modalities, verbal and spatial. Mean scores for all memory tasks were lower than normal. Aphasia score was significantly correlated with performance on all memory tasks. Correlation coefficients for short-term memory and working memory were approximately of the same magnitude. According to our findings, severity of aphasia is related with both verbal and spatial memory deficits. Moreover, while aphasia score correlated with lower scores in both short-term memory and working memory tasks, the lack of substantial difference between corresponding correlation coefficients suggests a possible primary deficit in information retention rather than impairment in working memory.

1. Introduction

The relationship between language and memory processing has been discussed in several studies (e.g. Howard & Nickels, 2005; Jacquemot & Scott, 2006; Nickels, Howard, & Best, 1997). Moreover, a wide variety of memory deficits has been reported in the aphasia literature. These deficits often implicate short-term memory (STM) (Beeson, Bayles, Rubens, & Kaszniak, 1993; Caramazza, Basili, Koller, & Berndt, 1981; Francis, Clark, & Humphreys, 2003; Friedrich, Martin, & Kemper, 1985; Heilman, Scholes, & Watson, 1978; Koenig-Bruhin & Studer-Eichenberger, 2007; Laures-Gore, Marshall, & Verner, 2011; Martin & Ayala, 2004; Ostergaard & Meudell, 1984) and working memory (WM) (Francis et al., 2003; Kolk & van Grunsven, 1985; Laures-Gore et al., 2011; Miyake, Carpenter, & Just, 1994). STM refers to one's ability to retain information in consciousness for a short period of time (usually a few seconds) and is a prerequisite for WM, which refers to one's ability to manipulate the transiently available information. Deficits in both are found in Broca's as well as in Wernicke's aphasia (De Renzi & Nichelli, 1975; Ostergaard & Meudell, 1984), transcortical sensory aphasia (Jefferies, Hoffman, Jones, & Lambon Ralph, 2008), and conduction aphasia (Baldo, Klostermann, & Dronkers, 2008; Heilman et al., 1978; Sakurai et al., 1998). Regarding conduction aphasia in particular, some authors stress the idea that it is partly a STM disorder (Shallice & Warrington, 1977).

Interestingly, such memory deficits in aphasia do not seem to be limited to verbal memory, but they also implicate visuospatial memory. Aphasic patients are found to have an impairment of spatial memory when tested with the Corsi block-tapping task (De Renzi & Nichelli, 1975; Martin & Ayala, 2004). A reduced spatial span has also been reported in individuals suffering from various aphasic syndromes (Albert, 1976). Given that spatial memory is thought to be mainly mediated by right hemisphere structures, such findings seem paradoxical (Burgio & Basso, 1997), but not if one adopts the notion that verbal strategies are necessary to respond in spatial memory tasks (Baldo & Dronkers, 2006). Moreover, memory impairments are associated with left perisylvian lesions involving the inferior parietal lobule, the posterior aspect of the superior temporal gyrus (Wernicke's area), the middle temporal gyrus, and anterior perisylvian structures including Broca's area (see Gordon, 1983) that are also implicated in language. However, Burgio and Basso (1997) claim that these memory impairments are independent from the presence of aphasia and are due to lesions of the left cerebral hemisphere in general.

In the present study we investigated whether aphasic patients demonstrate STM and WM deficits or not, and if so, in which modality: verbal, spatial, or both. Specifically we addressed three questions: (1) *Are aphasic and memory deficits due to a compromized common mechanism*? If this were the case, the degree of severity of aphasia would covary with the severity of memory deficits. (2) *Does this hypothesized common mechanism specifically concerns the verbal*

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or the spatial material as well? If the memory deficit were specific to language, severity of aphasia would covary only with verbal memory performance; otherwise, it would covary with both verbal and spatial memory performance. (3) *Is the common mechanism part of STM or WM*? If it were part of STM, severity of aphasia would covary with both STM and WM. If it were part of WM, a stronger correlation would be expected between WM and severity of aphasia.

2. Methods and participants

58 right-handed aphasic patients (15 women), 24–84 years old (mean: 61.33; SD: 13.30), participated in this study. Time post onset (TPO) ranged from 4 to 240 weeks (mean TPO: 58.74 weeks). CT and/or MRI scans were obtained and lesion sites were identified by two independent neuroradiologists. All patients underwent neurological examination. No visual deficit was reported by the neurologist. Each patient was assessed separately by a clinical neuropsychologist. The Boston Diagnostic Aphasia Examination – Short Form (BDAE-SF) adapted in Greek (Tsapkini, Vlahou, & Potagas, 2009) was used for assessing language deficits. Four additional memory tests were administered: WAIS-III digits forward for assessing verbal STM, WAIS-III digits backward for assessing verbal WM, and the Corsi block-tapping task for assessing spatial memory. Memory tests were administered according to standard administration procedures. Any human data included in this manuscript was obtained in compliance with regulations of the Eginition Hospital ethics committee.

In the present study, specific BDAE-SF subtests were used: the auditory sentence comprehension subtest, and the oral expression subtest. In the auditory sentence comprehension subtest, the patient is asked to execute a command spoken by the examiner. The stimuli range from simple (e.g. a two-item command, such as "show me the ceiling, and then the floor", where the patient receives a maximum of a two-point score) to more complex commands (e.g. a five-item command, such as "tap each shoulder twice with two fingers, while keeping your eyes closed", where the patient receives a maximum of a five-point score). In the oral expression subtest, the patient is asked to describe what happened to him/her (stroke story). In the present study, the stroke story was recorded and then speech rate (words/minute) was calculated for each patient, by two independent judges (inter-rater consistency: $r = 0.98$, $p < 0.001$).

2.1. Calculation of the aphasia score

BDAE-SF already includes an aphasia severity scale. However, it is a qualitative six-point scale, thus offering little information. That is why we decided to create a simple aphasia score, based on the auditory sentence comprehension subtest, and the oral expression subtest, since comprehension and fluency are the most efficient indices of aphasia severity (Goodglass & Kaplan, 1972). Since it is methodologically incorrect to add scores that are not related with each other in any way, we explored the possibility of a relationship between the two scores. Analyses using Pearson r revealed a statistically significant correlation between scores in the two language subtests ($r = 0.48$, $p < 0.001$). This allowed the calculation of a total aphasia score (AS). The scores of the two BDAE-SF subtests were adjusted, so as to range between 0 and 10. We defined AS as the total (adjusted score for fluency plus adjusted score for comprehension).

3. Results and discussion

Every patient's span length, span score (number of correctly remembered trials), and product score (the product of the span length and the number of correctly remembered trials) were calculated for each test, according to Kessels, van den Berg, Ruis, and Brands (2008). Individual patients' span product scores and AS are shown in Table 1.

It could be speculated that a severe fluency deficit would result in an extremely low verbal span score, even in the absence of any memory disorder (Burgio & Basso, 1997). If a patient with no memory deficit cannot produce speech, then he/she will be unable to repeat even one or two digits, thus scoring extremely low in the digit span test. Therefore, he/she will be wrongly classified as a patient with a verbal memory deficit, while his/her low span should not be attributed to memory impairment. Moreover, severely impaired comprehension can result in misleading scores regarding almost any test of cognitive ability. If a patient cannot understand what he/she is asked to do, then his/her performance will be diminished, but this reduced score should be attributed to a comprehension, rather than a memory deficit.

In order to avoid such a confounding due to aphasic deficits regarding comprehension and speech output, patients with severe language deficits were excluded, before conducting the statistical analyses. For digit span forward and backward, patients who could not repeat at least one 2-syllable word (of the BDAE-SF word repetition subtest) or lacked the ability to execute a simple, one-item command (from the BDAE-SF sentence comprehension subtest) were excluded (patients 7, 15, 19, 24, 28, 32, 33, 34, 42, 45, 46, 49, 51, 52). Thus, 44 patients (11 women), 24–84 years old (mean: 59.77; SD: 14.42) were finally included in the analyses regarding digit span forward and backward (mean TPO: 60.04 weeks). For the Corsi block-tapping task, since a verbal response is not required, only patients who could not execute a simple, one-item command (from the BDAE-SF sentence comprehension subtest) were excluded (patients 15, 24, 45, 49). In this case, 54 patients (14 women), 24–84 years old (mean: 61.15; SD: 13.66) were finally included in the analyses regarding Corsi block-tapping task (mean TPO: 60.60 weeks).

One-sample t-tests revealed lower than expected product scores for all memory tasks [critical value for forward digit span: 50 ($t = -18.054$, $p < 0.001$), critical value for backward digit span: 26 ($t = -17.272$, $p < 0.001$), critical value for spatial forward span: 38 ($t = -3.832$, $p < 0.001$), critical value for backward spatial span: 38 ($t = -9.626$, $p < 0.001$)]. Critical values were decided on the basis of normative data by Kessels et al. (2008), where mean performances for 246 healthy older adults were presented. Means and standard deviations for patients' scores are shown in Table 2.

Given that the age range in our sample is quite large and that memory declines with age in the normal population, it could be proposed that separate norms should be used for different age groups. However, such norms were not used for each individual aphasic in our sample for several reasons. First of all, Kessels et al. (2008) found that age and education related effects were below 0.30 which is rather small (Cohen, 1992). Secondly, they did not find a gender effect. Moreover, the main aim of this study is not to demonstrate memory deficits in aphasic patients, but to investigate the possible relations between performance in memory tasks and severity of aphasia. For the aforementioned reasons we concluded that there was no need for using separate norms and therefore we did set a critical value for each t-test based on the normative data provided in Kessels et al. (2008). However, correlation analyses in our study were performed with age and education as control variables (see below).

The deficits found in our aphasic sample are not specific to verbal modality, because our patients showed impaired performance in the verbal and the spatial memory tests. Deficits in overall visual memory have also been found in other studies (Locke & Deck, 1978; Ostergaard & Meudell, 1984). Moreover, low performances are reported regarding Corsi block tapping task in particular (De Renzi & Nichelli, 1975; Martin & Ayala, 2004).

One should keep in mind, though, that a group of 58 aphasic patients cannot be considered as a homogenous group and the interpretation of group data needs some caution. In order to avoid bias, we did not select specific patients, but only excluded the ones that could not perform the task due to language problems. As can be seen in Table 1, some patients suffer from verbal memory deficits, others from spatial memory deficits, others from both, and others do not.

The main aim of this study was to explore possible relationships between linguistic and memory deficits in aphasic patients. Partial correlations were calculated between AS and product scores in the four memory tasks controlling for age and years of formal schooling. AS was significantly correlated with patients' performances in WM and STM tasks, and in both modalities, verbal and spatial (Table 3).

The correlation was stronger for verbal memory than for spatial memory tasks. However, correlation coefficients between WM