

CASE STUDY

Multimodal therapy of word retrieval disorder due to phonological encoding dysfunction

AGNÈS WEILL-CHOUNLAMOUNTRY^{1,2}, NATHALIE CAPELLE¹,
CATHERINE TESSIER¹, & PASCALE PRADAT-DIEHL^{1,3}

¹AP-HP, groupe hospitalier Pitié-Salpêtrière, Service de médecine physique et de réadaptation, Paris, France,
²Eru-22-LURCO, 72300 Sablé-sur-Sarthe, France, and ³Er-6-UPMC, 75013 Paris, France

(Received 21 January 2012; revised 4 August 2012; accepted 14 January 2013)

Abstract

Objective: To determine whether phonological multimodal therapy can improve naming and communication in a patient showing a lexical phonological naming disorder. This study employed oral and written learning tasks, using an error reduction procedure.

Methods: A single-case design computer-assisted treatment was used with a 52 year-old woman with fluent aphasia consecutive to a cerebral infarction. The cognitive analysis of her word retrieval disorder exhibited a phonological encoding dysfunction. Thus, a phonological procedure was designed addressing the output phonological lexicon using computer analysis of spoken and written words. The effects were tested for trained words, generalization to untrained words, maintenance and specificity. Transfer of improvement to daily life was also assessed.

Outcomes and results: After therapy, the verbal naming of both trained and untrained words was improved at $p < 0.001$. The improvement was still maintained after 3 months without therapy. This treatment was specific since the word dictation task did not change. Communication in daily life was improved at $p < 0.05$.

Conclusions: This study of a patient with word retrieval disorder due to phonological encoding dysfunction demonstrated the effectiveness of a phonological and multimodal therapeutic treatment.

Keywords: Aphasia, rehabilitation, language

Introduction

Naming comprises the ability of a speaker to produce either verbally or in writing the name of an object, a drawing, a picture or a sound. Naming is commonly analysed through a computational model of speech production within a two-step model of lexical access [1, 2], a semantic step and a phonological step. Naming requires an activation of the target word's semantic features from the mental lexicon which enables word retrieval and, following this step, the phonological form of the word is retrieved by the process of phonological encoding, with phonemes ordered in such a way that the word

may be articulated following a process of phonetic encoding.

Patients with aphasia may have phonological errors of speech production. Phonological errors may be due to lexical retrieval difficulties due to a failure of access to the phonological step. Omissions of phonemes or substitutions by others in a word may be due to phonological encoding disorders at the phonological step and may appear as non-word production in people with fluent aphasia.

Several therapeutic studies [3–5] have been devoted to determine the most efficient facilitation cues in naming therapy or to assess the maintenance of the results over time. They have shown that it is

possible to improve the overall output of words in aphasic patients by using phonological tasks such as repetition and rhyming or semantic tasks such as picture naming, word and picture matching and categorization [6–8]. Wisenburn and Mahoney [9] performed a meta-analysis of 44 studies and evaluated the efficacy of various approaches in treatment of naming disorders, possible generalization of these treatments on untrained-unexposed words and the maintenance of performance over time. They concluded that semantic, phonological and mixed therapies all showed benefits and that semantic therapy seemed to obtain more generalization to unexposed words. Nickels [10] also highlighted the advantage of semantic therapies for generalization to untrained words in contrast with phonological therapies for which this effect was less marked or even absent. In addition, there is a direct relationship between the nature of the word retrieval difficulties and the nature of the efficient treatments [11]. While semantic therapies are usually efficient for patients suffering a semantic disorder, phonological therapies are generally efficient for patients with a phonological disorder. More precisely, semantic and phonological therapies are effective for central semantic deficits and phonological or mixed phonological and semantic treatments are effective for phonological encoding disorders [5, 6, 12–15]. However, the relationship between the nature of impairment of word retrieval and its appropriate treatment is widely debated [10, 16, 17].

Phonological therapies include phonological facilitation or tasks. Some studies [18, 19] have shown that phonological facilitation has a short retention time when used alone, from a few minutes to 24 hours. When used in combination with other tasks (e.g. repetition, designation or any other semantic processing), phonological facilitation may improve naming for trained words with maintenance over time and may allow generalization to untrained words [20]. In a review of the various phonological therapies [21], most studies are shown to have involved patients with lexical retrieval difficulties, mostly due to a failure of the access into the phonological step.

These therapies differ depending on whether or not they use cues and whether they use isolated or combined cues. Phonological encoding disorders are not very susceptible to spontaneous recovery [6] and fairly resistant to facilitating cueing. Buttet-Sovilla and Laganaro [6] claim that strategies used in the treatment of phonological encoding disorders mostly rely on the improvement of phonological encoding (i.e. awareness of errors, knowledge of the phonological composition of words, training of phonological memory).

Ducarne de Ribaucourt [22] has developed empirical therapies in an attempt to reorganize the access to the phonological representations through multimodal procedures. All forms of transcoding were able to contribute to the strengthening of the phonological pattern; although the written modality (e.g. grapho-phonemic conversions) was used preferentially. The effectiveness of orthographic and phonological cueing on picture naming was confirmed in a recent study [21]. Orthographic cues (giving the patient the first written CV syllable) improved performance in word-finding for seven out of eight patients and this improvement was maintained 1 week post-therapy. This effectiveness of orthographic cueing might be linked to the effort made by the patient in order to find the word: using a spelling cue and not only word repetition or reading the word aloud [23] would, thus, result in a more thoroughgoing treatment. Other studies with multimodal procedural naming therapy have confirmed that written naming has a positive impact on oral naming [3, 24–26]. The links between oral and written modalities in therapeutic programmes have also been described in recent articles [27, 28]. Beeson et al. [29] had noticed that, during therapy of written naming, patients spontaneously repeated the target-word several times when writing under dictation and that this improved their performance in verbal naming. Based on these clinical observations, they incorporated the treatment of oral naming their Copy and Recall Treatment (CART) Protocol, a written naming therapy [27]. In the CART Protocol, the patient is first asked to reconstitute the word using mobile letters, to spell it, then to copy it and finally to write it correctly three times. Beeson et al. modified the CART procedure by adding verbal repetition of trained words. This ‘CART + Repetition’ procedure constitutes a multimodal naming therapy which incorporates a verbal modality (repetition) in a protocol aimed at stimulating the written modality, therefore combining stimulation of both written and verbal modalities. Beeson et al. compared two therapies: the ‘CART + Repetition’ procedure and a verbal repetition procedure, which did not include any orthographic training. The ‘CART + Repetition’ procedure induced a significant improvement in written naming. A significant improvement in verbal naming was also occasionally observed when the patient had correct residual phonological abilities. This demonstrated that there is a reinforcement link between phonology and orthography. Wright et al. [28] used the ‘CART + Repetition’ [27], in order to study the impact of cued written naming on verbal naming in two patients. The treatment involved a written cueing hierarchy procedure, with verbal and written naming of a picture. The patient was asked to produce the word and then to write it. If

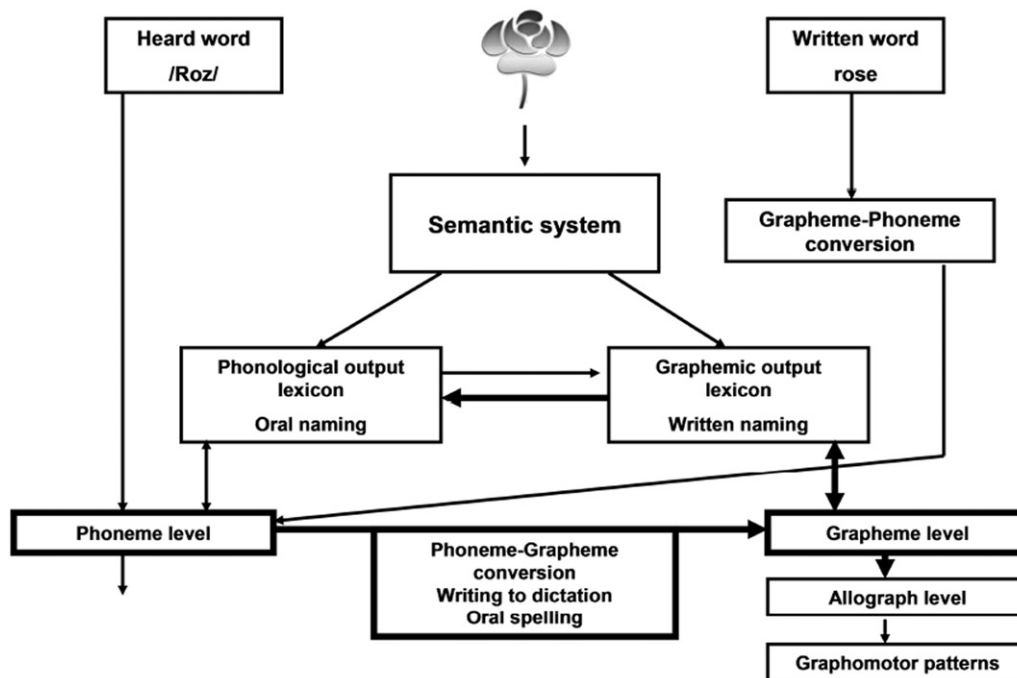


Figure 1. Lexical model according to Kiran [31] adapted from Ellis and Young [32]. Graphemic representations for written words are predicted to be available during written naming tasks. Kiran claimed a bidirectional connection between written and oral naming to facilitate improved oral naming of items.

spoken naming was successful but written naming was unsuccessful, the patient was asked first to copy the target word 3-times, then to write and verbally state the word from memory 3-times. If the verbal production was incorrect or absent, the patient was asked to write the word. Only when the word was correctly written was the next word presented. Although the two participants in this study demonstrated an improvement in their verbal naming abilities for the targeted items, they responded differently to the treatment. The first patient maintained verbal naming gains 4 weeks after therapy and improved naming to untrained items, while the other patient did not maintain his performance and showed no generalization to untrained items. Wright et al. [28] hypothesizes that this difference can be partially explained by the fact that, in the first and not in the second participant, the graphemic output link between the semantic system and the orthographic output lexicon was defective [28]. All these results strongly suggest that treatment in one output modality can improve performance in another.

According to Kiran et al. [30], training grapheme-phoneme conversions could improve verbal and written naming as well as writing to dictation, while providing a generalization effect to untrained items [30]. Training phoneme to grapheme conversion by writing to dictation would improve performance in verbal and written naming [31]. Based on these results, Kiran et al. proposed a modified

version of a lexical model [32] (Figure 1) by adding a bi-directional connection between the phonological output lexicon and the orthographic output lexicon. They hypothesized that training sub-lexical conversions could efficiently improve written and verbal naming and therefore proposed to treat verbal and written output modalities simultaneously rather than successively in naming therapies; the method they developed was more efficient in improving lexical deficits than the standard therapeutic programmes, which only targeted one output modality at a time.

Besides addressing different aspects of lexical processing, different learning approaches are also used in therapies for anomia. Learning approaches can be thought of as involving two factors: (i) the error rate that is the scope left to the patient to produce errors and (ii) the effort required of the patient to produce the correct answer. As far as error rate is concerned, the various learning approaches are classified as follows: errorless learning, error reduction learning and errorful learning. Errorless learning is an approach using descending cueing hierarchies in a task to prevent errors. Errorful learning uses ascending cueing hierarchies in tasks in which errors are allowed and error-reducing learning, as an intermediate approach between errorless learning and errorful learning to reduce the potential for error. The principle of error reduction learning is to provide sufficient cues to inhibit errors. This is

supposed to avoid the patient learning his own mistakes. Cues are then provided according to the vanishing cues technique in order to make the task less artificial and introduce effort [33]. The efficacy of errorless learning was first described in amnesic patients [34] and more recently several studies have endeavoured to compare different learning approaches in aphasic patients [35, 36], in anomia and in central auditory deficits [37, 38].

Most studies have reported positive outcomes using errorless learning for word finding treatments [35, 36, 39, 40]. They show equivalent improvement for errorless and errorful strategies [40, 41] and also equivalent maintenance for errorless and errorful learning [36].

In the present study a patient with fluent aphasia was used in a single-subject experimental therapeutic procedure using a word retrieval therapy computer program for aphasic adults, 'Au Fil Des Mots' [42]. This software suite offers three multimodal (oral and written) procedures, each of them being specifically designed for the rehabilitation of one of the following word-finding difficulties: lexical semantic impairments, anomia or lexical phonological impairments. The learning approach relies on error reduction, the software forbidding the visualization of errors in written naming. It includes a library of 560 pictures, which have been selected such that their characteristics enable manipulation of word frequency and length. The software is part of a complete aphasia rehabilitation programme. It requires the presence of a therapist, who must select and validate the procedure to be used in the treatment of lexical impairments, in particular the items on which to be trained and the rate at which item difficulty increases.

The objective was to determine whether a phonological multimodal computerized therapy involving both oral and written tasks, using error reduction learning, may improve naming and communication in a patient showing a lexical phonological naming disorder. A single case design was used in the context of clinical rehabilitation for a case of aphasia. Effects were tested for trained words, generalization to untrained words, maintenance, transfer to daily life and specificity.

Patient and method

Clinical report

The patient, HA, is a 52 year old right-handed French-speaking woman. She had received a low level of education and worked as a cleaner. She had suffered a cerebral infarct (Figure 2), which caused fluent aphasia. An aphasia test [43] administered in July 2007, 1 month after the stroke, showed that HA's spontaneous oral language was fluent but poor in content. Her errors were primarily phonological; phonological paraphasias (lavabo = /lavamo/) and non-words (dent = /skar/; vache = /froji/; marguerite = /karafut/), with repeated attempts (*conduite d'approche*) and these phonological errors were across all modalities of naming, reading aloud and repetition. There was a word length effect. Oral comprehension was impaired with a marked length effect. Written language was also an impaired jargonaphasia with graphemic errors and neologisms. Reading was disturbed and the patient was unable to read any sentence. Written comprehension was relatively preserved. Her performance in auditory comprehension tasks on single words (15/15) and in written comprehension tasks (word picture

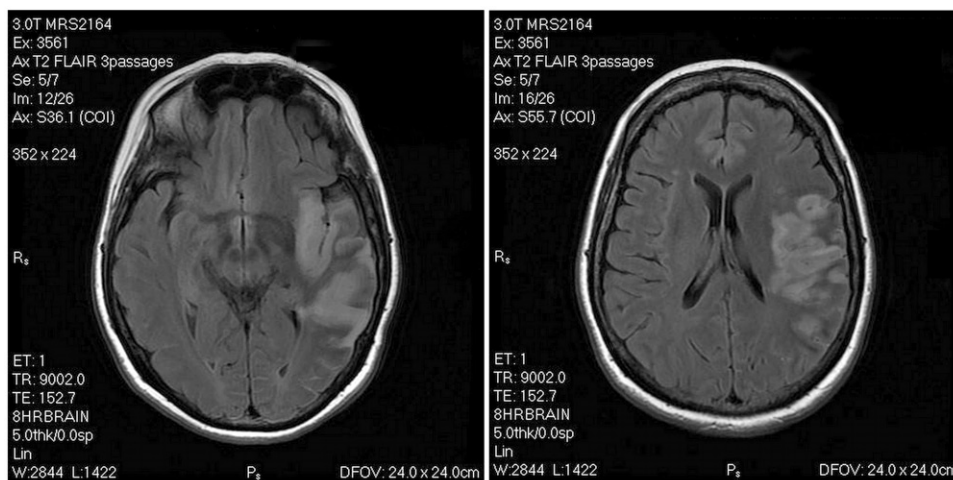


Figure 2. MRI: T2-weighted axial images revealed hyperintense signal and demonstrated an ischemic event located in the left temporoparietal lobes and insular region.

matching) (25/25) was preserved, whereas her performance in oral tasks such as picture naming (1/20), word repetition (11/25) and oral reading (7/25) revealed phonological errors. This preservation of comprehension (spoken and written) showed retention of the conceptual knowledge in the mental lexicon while spoken output was impaired, phonological errors occurred on all output tasks and an impairment was revealed of the phonological output lexicon.

Thus, naming errors were mostly phonological, such as phoneme omission or substitution in words and non-words, this kind of error could be explained by the impairment of phonological encoding disorders at the phonological level. HA also exhibited a repetition conduction aphasia, as described by Shallice and Warrington [44] with a phonological short-term memory deficit. Under the hypothesis that word retrieval disorder might be explained by the phonological encoding deficit resulting from a disturbance of the output phonological lexicon, it was decided to set up word retrieval therapy with phonological analysis.

The experimental nature of the therapy was explained to the patient who gave her informed consent to participate.

Description of the therapy

A computer-assisted technique ‘*Au fil des mots*’ was employed, with a phonological procedure addressing the output phonological lexicon. This technique is highly constrained, such that the patient is trained to correctly verbalize through the written modality using error reduction learning (Figure 3). The patient writes the words on the computer keyboard. During training, the target picture appears on the screen, following which:

- (1) The name of the picture appears under the picture as a non-word, with jumbled letters. The patient is then required to arrange the letters in the correct order. This must be done silently.
- (2) When the graphemes are correctly ordered, the computer emits each grapheme, each syllable and eventually the whole word. The patient must repeat each grapheme and syllable produced by the computer, and then verbalize the whole word. (for example: /b//a/-/ba/-/l//e/-/lɛ/-/ba|ɛ/)
- (3) The patient is asked to copy the word and simultaneously pronounce each letter, syllable and then the whole word.

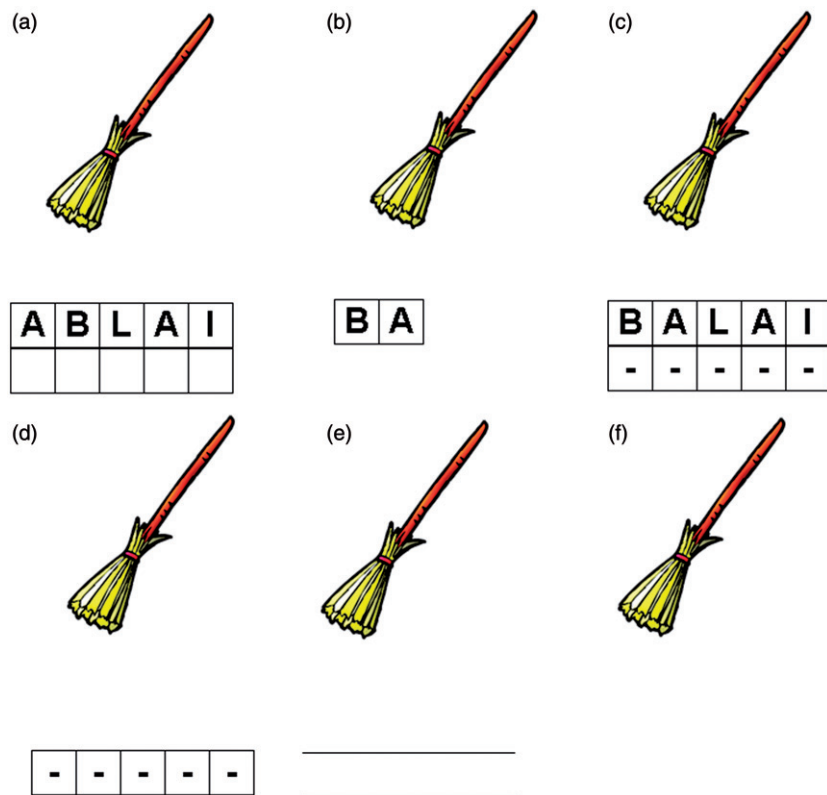


Figure 3. ‘*Au fil des mots*’ screen shots and instructions for each step of verbal naming training. (a) Place the letters of the target word in the correct order while silent. (b) Spell the word while speaking out loud each letter, each syllable and then repeat the whole word. (c) Copy the word while simultaneously spelling each letter aloud. (d) Copy the word after it has faded away and read it aloud. (e) Write the word. (f) Speak the word.

Table I. Dictation task, ECVB and number of failed and successful picture naming with di, tri and multisyllabic words at each assessment.

	FA				A1				A2				A3				LA			
	Di	Tri	Multi	Total	Di	Tri	Multi	Total	Di	Tri	Multi	Total	Di	Tri	Multi	Total	Di	Tri	Multi	Total
Naming task 'Au fil des mots' 90 trained words	26	31	33	90	26	31	33	90	26	31	33	90	26	31	33	90	26	31	33	90
Successful naming	0	0	0	0	<i>24</i>	<i>14</i>	<i>9</i>	<i>47</i>	<i>22</i>	<i>27</i>	<i>16</i>	<i>65</i>	<i>24</i>	<i>27</i>	<i>22</i>	<i>73</i>	<i>23</i>	<i>28</i>	<i>24</i>	<i>75</i>
Naming task (DO-80) 69 untrained words	51																			64
successful naming																				
Dictation task 25 untrained words	9																			12
successful writing																				
ECVB score (/102)	54																			74

FA, first assessment, performed 1 month before the start of the therapy; A1, assessments after training for disyllabic words (R1); A2, assessments after training for trisyllabic words (R2); A3, assessments after training for multisyllabic and compound words (R3); LA, last assessment, 2 months later. The dictation task is taken from Ducarne de Ribaucourt's [43] Aphasia Test; ECVB, Echelle de communication verbale de Bordeaux [46]. Significant scores on the McNemar change test are shown in italics.

- (4) The picture now appears on the screen in the absence of the associated word. The patient is then asked to type the word (delayed copy), to simultaneously pronounce each letter, syllable and then eventually to repeat the word.
- (5) The patient is asked to write the name of the picture as described above.
- (6) Finally, the patient is asked to pronounce the word.

HA failed to name 90 of 359 no-trained pictures from 'Au fil des mots'. The corresponding 90 words were used in the baseline naming task. They were divided into three sets for each treatment step (26 R1, 31 R2 and 33 R3).

A difficulty hierarchy was chosen based on a word length criterion. The length of the trained words was increased at each step of the rehabilitation programme: initially, 26 disyllabic words were trained (R1), then 31 trisyllabic words (R2) and eventually words having over three syllables and compound words were trained during R3 (33 multisyllabic words). Each level of difficulty was attempted only after the preceding one had been mastered.

Five words were trained in each session. In the following training session, the therapist checked that the patient could name the five trained pictures both orally and writing. Successfully trained items were then listed as acquired words and were not trained anymore. The failed words were trained again. New words were added such that the patient has always to process a set of five words.

The experimental design consisted of four phases: three treatment phases, followed by a break of 2 months, during which no therapy or assessment was carried out.

To assess the effect and the specificity of the multimodal therapy, five assessments were performed. A first assessment (FA) was performed before the beginning of the therapy. Two assessments took place during the therapy, after R1 (A1) and after R2 (A2). Another assessment (A3) was performed just after R3 at the end of therapy. Two months later, a last assessment (LA) was performed in order to assess the maintenance of the performance level after therapy.

The main criterion was the number of successfully named pictures. During the FA and the LA assessments periods, selections of sub-tests or cognitive assessments (see Table I) were administered. Only the specific assessment of the 90 trained words was conducted 5-times.

- (1) The global effect of the therapy was assessed by comparing LA to FA. Each step of difficulty was also compared with every other. The therapeutic improvement was assessed by comparing each step of difficulty in word length.
- (2) The long-term maintenance of the therapy on the 90 trained words was assessed by comparing LA to A3. The stability in naming performance was assessed in DO 80. The set of the 69 words from DO 80 contains 31 monosyllabic words, 26 disyllabic words, nine trisyllabic words and three multisyllabic and compound words. To assess the stability of performance in naming in relation to length, a comparison was performed at LA and FA for two sets: the first set contained the 31 monosyllabic words and the second set contained the other lengths which were trained during the therapy.
- (3) The generalization to untrained words was assessed using the DO 80 [45] oral

picture-naming test which did not present matched sets of nouns in terms of imageability or frequencies. This test provides a set of 80 black and white pictures, out of which 11 corresponded to words already trained in the computer therapy. The remaining 69 pictures were used to test the generalization of naming performance to untrained words.

- (4) Communication in daily life was assessed using the ‘*Echelle de Communication Verbale de Bordeaux*’ (Bordeaux Verbal Communication Scale) [46]. This scale is a communication impairment evaluation scale which aims to identify the daily-life situations in which aphasics suffer the most difficulty. It includes 34 items in a semi-directed interview. The topics include expressing one’s needs, intents and projects, talking with relatives and strangers and functional communication.
- (5) The specificity of the rehabilitation was assessed by administering the word dictation test from the Aphasia Examination [43]. The hypothesis

was that HA’s performance for this dictation test should not improve.

- (6) The specific assessment of the 90 trained words was conducted 5-times. DO 80, dictation and disability in daily life were only assessed before (FA) and after (LA) therapy.

We compared the proportion of failed and trained words at different stages of the therapy.

The McNemar change test was conducted to test for significance. The significance level was set at $p < 0.05$. The experimental therapy began 10 months after the neurological event and was carried out 3-times a week.

Results (Tables I and II)

Effect of the therapy on the 90 trained picture naming words (Figure 4)

The performance improvement in the 90 trained words naming task immediately following the last

Table II. Statistical analysis (McNemar change test) of naming improvement for the 90 trained words (programme ‘*Au fil des mots*’) between FA and LA. The rehabilitation programme contained three steps: 26 bisyllabic words were trained (R1), 31 trisyllabic words (R2) and eventually words having over three syllables and compound words were trained during R3 (33 multisyllabic words). The assessments after each step were A1 (R1), A2 (R2) and A3 (R3).

	90 words		Disyllabic		Trisyllabic		Multisyllabic	
	χ^2	p	χ^2	p	χ^2	p	χ^2	p
FA/LA (Overall effect)	73.01	<0.001	21.04	<0.001	26.04	<0.001	22.04	<0.001
FA/A3	72.01	<0.001	23.04	<0.001	25.04	<0.001	20.05	<0.001
FA/A1 (R1)	45.02	<0.001	22.04	<0.001	12.07	<0.001	7.11	0.007
A1/A2 (R2)	11.17	<0.001	0.50	0.47	10.56	<0.001	3.27	0.07
A2/A3 (R3)	2.45	0.11	0	1	0	1	2.76	0.09
A3/LA (Maintenance)	0.05	0.83	0	1	0	1	0.07	0.78

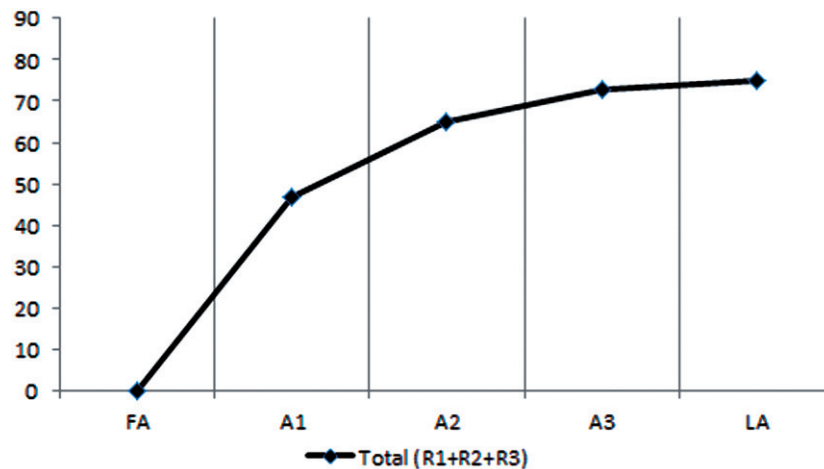


Figure 4. Picture-naming score for the 90 trained words for each assessment. FA, first assessment performed before the beginning of the therapy; A1 & A2, assessments during the therapy, after R1 (A1) and after R2 (A2); A3, assessment just after R3 at the end of therapy; LA, assessment 2 months after the end of therapy.

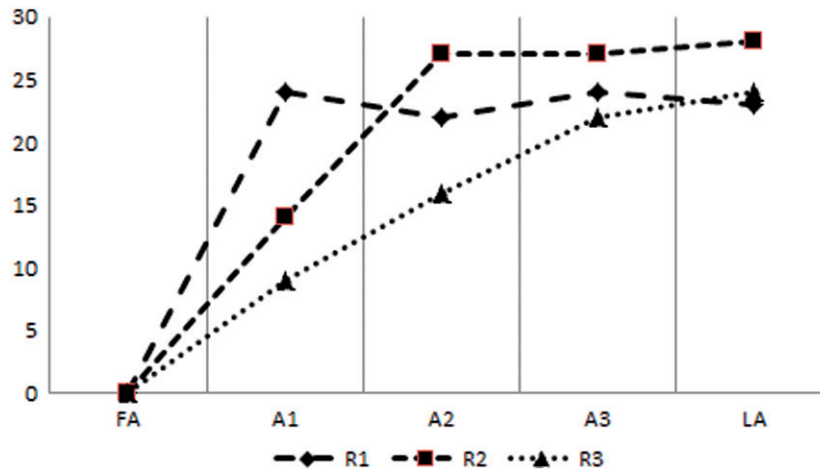


Figure 5. Picture naming scores depending on difficulty due to word length (R1, disyllabic words; R2, trisyllabic words; R3, multisyllabic words) for each assessment.

therapy (R3) was FA = 0% (0), A3 = 81 % (73) ($\chi^2(1, n=90) = 72.01, p < 0.001$). Furthermore, the performance improvement was also significant 2 months after therapy, FA = 0 % (0), LA = 83 % (75) ($\chi^2(1, n=90) = 73.3, p < 0.001$). Improvement was also significant when the first assessment before therapy was compared to the second assessment at the end of the first step of the therapy (R1), FA = 0% (0), A1 = 52% (47) ($\chi^2(1, n=90) = 45.02, p < 0.001$) and at the third assessment at the end of the second step of therapy (R2), FA = 0% (0), A2 = 75% (65) ($\chi^2(1, n=90) = 63.02, p < 0.001$).

Improvement during picture naming with words of increasing length (Figure 5)

HA's performance for disyllabic and trisyllabic words improved after the corresponding category had been specifically trained. Comparing FA and A1 shows that results for disyllabic words improved significantly at the end of the training of disyllabic words (R1) ($\chi^2(1, n=26) = 22.04, p < 0.001$). This comparison also shows that results for trisyllabic words significantly improved ($\chi^2(1, n=31) = 12.07, p < 0.001$). More trisyllabic words were retrieved after specific training (R2) (A1–A2, $\chi^2(1, n=31) = 10.56, p = 0.001$). Again, it is noticeable that the scores for multisyllabic and compound words also increased significantly when comparing FA to A1 ($\chi^2(1, n=33) = 7.11, p = .007$). Training multisyllabic and compound words did not significantly increase the scores for these words (R3: A2–A3, $\chi^2(1, n=33) = 2.76, p = 0.09$).

Maintenance of the therapy

Improvement was maintained after 2 months without therapy (A3–LA, $\chi^2(1, n=90) = 0.05, p = 0.83$).

At FA, the patient scored 27/31 for the first set of DO 80 (monosyllabic untrained words in the therapy) and scored 29/31 at LA. The difference was not statistically significant ($\chi^2(1, n=31) = 0.5, p = 0.479$) and revealed no modification in naming performance. For the second set of DO 80 (other lengths trained in therapy), HA scored 24/38 at FA and scored 35/38 at LA. This improvement was statistically significant ($\chi^2(1, n=38) = 7.69, p < 0.005$).

Generalization to untrained words

For the 69 words from DO 80 which had not been trained, the improvement between FA and LA was statistically significant ($\chi^2(1, n=69) = 9.6, p = 0.005$).

Transfer to communication in daily life

At FA, the patient scored at the ECVB 52% (54/102) and at LA she scored 72% (74/102). This 20-point improvement is statistically significant ($\chi^2(1, n=102) = 12.07, p < 0.05$). In addition, HA was said to be less embarrassed in expressing her intentions and telephoning an unknown person. She also initiated conversations with both her family and with unknown people.

Specificity

Performance in the word dictation task which was not addressed by the naming therapy was unmodified ($\chi^2(1, n=25) = 0.25, p = 0.617$).

Discussion

The present computer-assisted phonological therapeutic procedure significantly improved

spoken naming. Comparing the scores for the trained words showed a statistically significant improvement of naming performance after therapy. This improvement was not limited to the trained words, but was also significant for untrained words. Scores for tri, multisyllabic and compound words showed significant improvement after the training of disyllabic words. This improvement was also found in verbal communication during daily life activities. The improvement of trained words, the generalization to untrained words, the maintenance of the improvement and transfer to daily life activity demonstrates the effect of this therapy and its relevance for patients with phonological encoding disorder in spoken naming.

It is very unlikely that these improvements could be explained by spontaneous recovery, since therapy began 10 months after the initial stroke. Moreover, the dictation task used as a control task did not show any improvement.

The literature provides evidence that phonological encoding naming disorders may be improved by phonological procedures. Most of these therapies were based on Beeson and Egnor's CART + Repetition therapy. Similarly to the present study, the studies by Beeson and Egnor's [27], Wright et al. [28] and Buttet-Sovilla and Laganaro [15] included patients with cerebrovascular disease, all of whom showed fluent aphasia. The severity of aphasia and the severity of spoken naming impairment are similar in these studies and in the present study. If one considers the five patients included in these three studies, it is noticeable that, while the therapies proved efficient for trained words in all five patients, only three of the patients described exhibited generalization to untrained words and maintenance and that none of these studies addressed the patients' performance in daily life.

This therapy is close to those of Beeson and Egnor [27] and Wright et al. [28] (Table III), insofar as all of them used both spoken and written treatment to

improve spoken naming. Beeson and Egnor [27] performed a single-case study, the aim of which was to improve naming by combining treatments for written and spoken naming: 'CART + Repetition' protocol. They postulate that strengthened orthographic representation provided additional support to access phonology, which was the intended effect of treatment. However, the therapy described in the present paper differs in several aspects from Beeson & Egnor and Wright et al.'s therapies. These differences might explain why we, and not Beeson and Egnor, were able to find a generalization to untrained words. In fact, the training and the learning approaches were different on three points: (1) The timing of oral or written production; (2) Length hierarchy; and (3) Error-full or error-less learning.

(1) *The timing of oral or written production*

In Beeson and Egnor's [27] therapy, the repetition of the whole word is the very first step of the therapy. In this therapy, in a first written step, the patient is asked to silently arrange the letters of the target word in the correct order and, in a second verbal step, the patient is asked to repeat letters, syllables and eventually the whole word after they have been generated by the computer using written cueing. During all the steps of the computer assisted-therapy '*Au fil des mots*', the patient is requested to verbally produce the target word only during the written step. By presenting a written model, one expects to avoid, as far as possible, the patient making errors when producing spoken words. In addition, it is considered that presenting both the written and verbal forms of the word could channel the process needed to perform the right answer. This is in accordance with Buttet-Sovilla and Laganaro [15], who claim that metaphonological tasks may improve phonological encoding disorder. These authors report that naming therapies which require the patient to carry out phonological tasks have a fairly good

Table III. Comparison of this study with those of Beeson and Egnor [27] and Wright et al. [28].

	Beeson and Egnor [27] NEM	Wright et al. [28]		HA
		P1	P2	
Age	60	76	76	52
Delay post-onset	20 months	14 months	12 months	10 months
Aphasia	Fluent/conduction	Fluent	Fluent	Fluent/conduction
Duration of therapy	10 weeks	unknown	unknown	16 weeks
Number of sessions	unknown	unknown	unknown	21
Number of trained words	40	30	30	90
Effect on trained words	+	+	+	+
Generalization to untrained words	-	-	-	+
Maintenance	- 6 weeks	-4 weeks	-4 weeks	+8 weeks
Daily life improvement	NA	NA	NA	+

generalization effect, whereas classical isolated phonological tasks, which do not require the patient to carry out other tasks on the target word, do not. Like Buttet-Sovilla and Laganaro's [15] patient LM, HA benefitted from a phonological procedural therapy pairing various types of processing of the target word. However, this procedure is not comparable to that of Buttet-Sovilla and Laganaro, insofar as these authors did not specifically train naming.

(2) Length hierarchy

The procedure used a difficulty hierarchy based on a length effect of words, whereas Beeson and Egnor and Wright et al. therapies did not. The target words included in '*Au fil des mots*' are sorted by numbers of syllables (monosyllabic, disyllabic, trisyllabic and multi-syllabic or compound words). All series ordered by number of syllables improved significantly after the first training (R1). HA seemed to be receptive to the syllable length effect, since after the second training (R2), trisyllabic series still improved significantly. This result underlines the efficacy of a progressive rise of words' length in naming disorder treatments. This efficacy has also been shown in a previous study on specific rehabilitation of verbal working memory in a case of conduction aphasia [47, 48].

(3) Errorful or errorless learning

The Beeson and Egnor [27] and Wright et al. [28] therapies use an errorful learning procedure. In this approach, the cue is proposed to facilitate the patient's production after he has failed the task, while error reduction learning was used. At each level of difficulty, cueing was first systematically provided and then progressively faded out until, at the end of the task, the subject was asked to perform written and spoken naming without any cueing. This protocol was purposely chosen in order to keep, as far as possible, the patients from making errors. It is true that there is currently no study able to conclude which learning approach, errorful or errorless, would be the most effective for the improvement of spoken naming [49–52]. However, aphasics seem to prefer errorless learning [36], at least in the acute phase of their rehabilitation, i.e. during the first year after stroke. This might be linked to the encouragement brought by a correct response. However, over time, opinions seem to differ depending on the severity of anomia, with patients who suffer a persistent severe aphasia maintaining their preference for errorless learning. However, patients showing good recovery expect more improvement from errorful learning, considering that making an effort to provide a name might be positive and prompt them to continue the

therapy [21]. HA was no longer in the acute phase, but her aphasia stayed severe and, therefore, errorless learning seemed an appropriate technique.

The role of the quantitative aspects of therapy should be considered. Indeed, Beeson and Egnor [27] and Buttet-Sovilla and Laganaro [15] have claimed that the treatment must be sufficiently prolonged in order to obtain the generalization and maintenance of naming improvement to untrained words. Beeson and Egnor's therapy was 16 weeks long, while Buttet-Sovilla and Laganaro's experimental therapy lasted 6 months, as did this one. However, in these two studies, nothing is known about the number of sessions. The number of words trained might be critical. The study by Snell et al. [53] has shown that, when more words are given for anomia therapy, more words are learned and this appears to be true not only immediately after therapy but also after a follow-up period. In this study, 90 words were trained, vs 30 and 50 words, respectively, in the studies by Wright et al. [28] and Beeson and Egnor [27].

The maintenance of performance between the follow-up probes (2 months) was excellent. This maintenance is in agreement with Miceli et al. [13] and Hickin et al. [21] results. Hickin et al. [21], re-evaluating the phonological facilitation in a group of eight single cases, claimed that this facilitation could create a stable improvement provided that the patient was required to 'actively manipulate information/problem solve'. This was the case in this study, whereas the maintenance was stable in only three of five patients in previous studies. Furthermore, no variability in naming performances was found when comparing the different sets of DO 80 at FA and LA. Thus, improvements during successive treatments may not be interpreted as an improvement by chance, regardless of treatment.

The effect of the naming rehabilitation with '*Au Fil des Mots*' was specific, since the word dictation test did not show any significant improvement between the beginning and the end of the protocol.

In conclusion, this study describes a computer-assisted therapy of phonological encoding disorders. This treatment proved effective not only in improving naming in trained but also in untrained items and to improve communication in daily life. The effect is stable over time and the benefit is still present after a 2-month follow-up period. It is proposed that this efficacy is mainly linked to two characteristics of the procedure, i.e. its multimodal nature and the error-reduction approach used for training. These results will need to be confirmed in a forthcoming study involving more patients. The role of intensity and duration of rehabilitation and home-based training work will be explored.

Acknowledgements

The authors would like to thank Catherine Morin for reviewing this manuscript and offering helpful suggestions.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

References

- Goldrick M, Rapp B. Lexical and post-lexical phonological representations in spoken production. *Cognition* 2007;102: 219–260.
- Rapp B, Goldrick M. Discreteness and interactivity in spoken word production. *Psychological Review* 2000;107:460–499.
- Hillis A. Efficacy and generalization of treatment for aphasic naming errors. *Archives of Physical Medicine Rehabilitation* 1989;70:632–636.
- Howard D, Patterson K, Franklin S, Orchard-lisle V, Morton J. The facilitation of picture naming in aphasia. *Cognitive Neuropsychology* 1985;2:49–80.
- Le Dorze G, Pitts C. A case study evaluation of the effects of different techniques for the treatment of anomia. *Neuropsychological rehabilitation*. London: Psychology Press; 1995. pp 51–65.
- Buttet-Sovilla J, Laganaro M. In: in Aubin G, Belin C, David D, de Partz MP, editors. *Rééducation des troubles phonologiques: Une étude de cas*. Marseille: Solal; 2001. pp 57–73.
- Samson D. Evaluation et rééducation des troubles sémantiques (Actualités en pathologie du langage et de la communication). Marseille: Solal; 2001. pp 103–129.
- de Partz M-P. Revalidation des troubles du langage oral: Niveau lexico-sémantique. In: Seron X, Van der Linden M, editors. *Traité de neuropsychologie clinique*. Marseille: Solal; 2000. pp 131–146.
- Wisernburn B, Mahoney K. A meta-analysis of word-finding treatments for aphasia. *Aphasiology* 2009;23:1338–1352.
- Nickels L. Therapy for naming disorders: Revisiting, revising, and reviewing. *Aphasiology* 2002;16:935–979.
- Wisernburn B. Meta-analysis of anomia therapies in relation to underlying deficits. Annual Convention of the American-Speech-Language-Hearing Association. New Orleans, LA; 2009.
- Hillis A. Treatment of naming disorders: New issues regarding old therapies. *Journal of the International Neuropsychological Society* 1998;4:648–660.
- Miceli G, Amitrano A, Capasso R, Caramazza A. The treatment of anomia resulting from output lexical damage: Analysis of two cases. *Brain and Language* 1996;52:150–174.
- Robson J, Marshall J, Pring T, Chiat S. Phonological naming therapy in jargon aphasia: Positive but paradoxical effects. *Journal of the International Neuropsychological Society* 1998;4:675–686.
- Buttet-Sovilla J, Laganaro M. Troubles phonologiques: Rééducation du versant expressif. In: Solal, editor. *Actualités en pathologie du langage et de la communication*. Marseille: Solal; 2001. pp 57–73.
- Jacquemot C, Dupoux E, Robotham L, Bachoud-Levi AC. Specificity in rehabilitation of word production: A meta-analysis and a case study. *Behavioural Neurology* 2012;25: 73–101.
- Kiran S, Bassetto G. Evaluating the effectiveness of semantic-based treatment for naming deficits in aphasia: What works? *Seminars in Speech and Language* 2008;29:71–82.
- Best W, Herbert R, Hickin J, Osborne F, Howard D. Phonological and orthographic facilitation of word-retrieval in aphasia: Immediate and delayed effects. *Aphasiology* 2002;16:151–168.
- Patterson K, Purell C, Morton J. Facilitation of word retrieval in aphasia. In: Muller C, editor. *Aphasia therapy*. 2nd ed. Londres: Cole and Whurr Limited; 1983.
- Wiegel-Crump C, Koenigsnecht R. Tapping the lexical store of the adult aphasic: Analysis of the improvement made in word retrieval skills. *Cortex* 1973;9:411–418.
- Hickin J, Best W, Herbert R, Howard D, Osborne F. Phonological therapy for word-finding difficulties: A re-evaluation. *Aphasiology* 2002;16:981–999.
- Ducarne de Ribaucourt B. *Rééducation sémiologique de l'aphasie*. Paris: Masson; 1988. p 267.
- Basso A, Marangolo P, Piras F, Galluzzi C. Acquisition of new “words” in normal subjects: A suggestion for the treatment of anomia. *Brain and Language* 2001;77:45–59.
- Basso A. *Aphasia and its therapy*. New York: Oxford University Press; 2003.
- Deloche G, Dordain M, Kremin H. Rehabilitation of confrontation naming in aphasia: Relations between oral and written modalities. *Aphasiology*. London: Psychology Press; 1993. pp 201–216.
- Deloche G, Hannequin D, Dordain M, Metz-Lutz MN, Kremin H, Tessier C, Vendrell J, Cardebat D, Perrier D, Quint S, et al. Diversity of patterns of improvement in confrontation naming rehabilitation: Some tentative hypotheses. *Journal of Communication Disorders* 1997;30:11–21, quiz 21–22.
- Beeson P, Egnor H. Combining treatment for written and spoken naming. *Journal of the International Neuropsychological Society* 2006;12:816–827.
- Wright HH, Marshall RC, Wilson KB, Page JL. Using a written cueing hierarchy to improve verbal naming in aphasia. *Aphasiology* 2008;22:522–536.
- Beeson P, Hirsch F, Rewega M. Successful single-word writing treatment: Experimental analysis of four cases. *Aphasiology* 2002;16:191–202.
- Kiran S, Thompson CK, Hashimoto N. Training grapheme to phoneme conversion in patients with oral reading and naming deficits: A model-based approach. *Aphasiology* 2001;15:855–876.
- Kiran S. Training phoneme to grapheme conversion for patients with written and oral production deficits: A model-based approach. *Aphasiology* 2005;19:53–76.
- Ellis AW, Young AW. *Human cognitive neuropsychology*. Hove: Psychology Press; 1996.
- Abel S, Schultz A, Radermacher I, Willmes K, Huber W. Decreasing and increasing cues in baling therapy for aphasia. *Aphasiology*. London: Psychology Press; 2005. pp 831–848.
- Baddeley A, Wilson B. When implicit learning fails: Amnesia and the problem of error elimination. *Neuropsychologia* 1994;32:53–68.
- Fillingham J, Hodgson C, Sage K, Lambon Ralph MA. The application of errorless learning to aphasic disorders: A review of theory and practice. *Neuropsychological Rehabilitation*. London: Psychology Press; 2003. pp 337–363.
- Fillingham J, Sage K, Lambon Ralph M. The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation* 2006;16:129–154.
- Tessier C, Weill-Chounlamountry A, Michelot N, Pradat-Diehl P. Rehabilitation of word deafness due to auditory analysis disorder. *Brain Injury* 2007;21:1165–1174.
- Weill-Chounlamountry A, Soyez-Gayout L, Tessier C, Pradat-Diehl P. [Cognitive rehabilitation of amusia]. *Annales de Réadaptation et de Médecine Physique* 2008; 51:332–341.

39. Fillingham J, Sage K, Ralph MA. Treatment of anomia using errorless versus errorful learning: Are frontal executive skills and feedback important? *International Journal of Language and Communication Disorders* 2005;40:505–523.
40. McKissock S, Ward J. Do errors matter? Errorless and errorful learning in anomic picture naming. *Neuropsychological Rehabilitation* 2007;17:355–373.
41. Fillingham J, Sage K, Lambon Ralph MA. The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation* 2006;16:129–154.
42. Tessier C, Weill-Chounlamounry A. *Au fil des mots*. Ortho Editions; 2009.
43. Ducarne de Ribaucourt B. *Test pour l'examen de l'aphasie*. Paris: ECPA; 1989.
44. Shallice T, Warrington E. Auditory-verbal short-term memory impairment and conduction aphasia. *Brain and Language* 1977;4:479–491.
45. Deloche G, Hannequin D. *Test de dénomination orale d'images DO 80*. Paris: Editions du Centre de Psychologie Appliquée; 1997.
46. Darrigrand B, Mazaux J. *Echelle d'évaluation de communication verbale de Bordeaux*. Isbergues: Ortho Edition; 2000.
47. Pradat-Diehl P, Tessier C, Vallat C, Mailhan L, Mazevet D, Lauriot-Prevost MC, Bergego C. Conduction aphasia and phonemic disorder. *Revue Neurologique* 2001;157:1245–1252.
48. Vallat C, Azouvi P, Hardisson H, Meffert R, Tessier C, Pradat-Diehl P. Rehabilitation of verbal working memory after left hemisphere stroke. *Brain Injury* 2005;19:1157–1164.
49. Conroy P, Sage K, Ralph MAL. Errorless and errorful therapy for verb and noun naming in aphasia. *Aphasiology* 2009;23:1311–1337.
50. Fillingham JK, Hodgson C, Sage K, Lambon Ralph MA. The application of errorless learning to aphasic disorders: A review of theory and practice. *Neuropsychological rehabilitation*. London: Psychology Press; 2003. pp 337–363.
51. Fillingham J, Sage K, Lambon Ralph M. Further explorations and an overview of errorless and errorful therapy for aphasic word-finding difficulties: The number of naming attempts during therapy affects outcome. *Aphasiology*. London: Psychology Press; 2005. pp 597–614.
52. Fillingham JK, Sage K, Lambon Ralph MA. The treatment of anomia using errorless learning. *Neuropsychological Rehabilitation* 2006;16:129–154.
53. Snell C, Sage K, Ralph MAL. How many words should we provide in anomia therapy? A meta-analysis and a case series study. *Aphasiology* 2010;24:1064–1094.

Copyright of Brain Injury is the property of Taylor & Francis Ltd and its content may not be copied or emailed to multiple sites or posted to a listserv without the copyright holder's express written permission. However, users may print, download, or email articles for individual use.