

Dissociation between singing and speaking in expressive aphasia: The role of song familiarity

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Abstract

There are several reports on the ability aphasic patients have to sing familiar songs, despite having severe speech impairments. Based on these observations it was also suggested that singing might improve speech production. However, recent experimental studies with aphasic patients found no evidence to illustrate that singing improves word production under controlled experimental conditions. This study investigated the role of singing during repetition of word phrases in a patient severely affected with non-fluent aphasia (GS) who had an almost complete lesion of the left hemisphere. GS showed a pronounced increase in the number of correctly reproduced words during singing as compared to speaking excerpts of familiar lyrics. This dissociation between singing and speaking was not seen for novel song lyrics, regardless of whether these were coupled with an unfamiliar, a familiar, or a spontaneously generated melody during the singing conditions. These findings propose that singing might help word phrase production in at least some cases of severe expressive aphasia. However, the association of melody and text in long-term memory seems to be responsible for this effect.

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1. Introduction

An impressive phenomenon in some patients with severe expressive aphasia is their preserved ability to sing familiar songs although they are widely unable to speak (Amaducci, Grassi, & Boller, 2002; Hebert, Racette, Gagnon, & Peretz, 2003; Jacome, 1984; Smith, 1966; Sparks, Helm, & Albert, 1974; Warren, Warren, Fox, & Warrington, 2003; Yamadori, Osumi, Masuhara, & Okubo, 1977). It has been suggested that preserved brain circuits, which are involved in the representation and production of sung lyrics (Amaducci et al., 2002; Samson & Zatorre, 1991; Yamadori et al., 1977), may cause this ability. This implies that singing words might depend on brain circuits other than those used when speaking words, and that in some aphasic patients, only those brain areas serving the generation

of speech are lesioned. In relation to familiar songs, it has been proposed that separable stores for text, songs (melody and text; Crowder, Serafine, & Repp, 1990; Samson & Zatorre, 1991; Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986), and melody (Steinke, Cuddy, & Jakobson, 2001) might exist. From this point of view, lesions in areas involved in the representation and production of lyrics would not necessarily affect the representation and production of songs.

Differential hemispheric specialisation in particular was proposed to underlie singing and speaking in most right-handed subjects. While speaking would predominantly depend on the left hemisphere, singing would be a function of the right hemisphere (Albert, 1998; Jeffries, Fritz, & Braun, 2003; Patel, 2003; Samson & Zatorre, 1991, 1992; Smith, 1966; Sparks & Deck, 1994). This account could explain why aphasics with extended left-hemispheric lesions and a preserved right hemisphere are able to sing (e.g., Amaducci et al., 2002; Smith, 1966; Warren et al., 2003; Yamadori et al., 1977). In contrast, right hemispheric lesions should impair the ability to sing but not the ability

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to speak (Bautista & Campetti, 2003; Confavreux, Croisile, Garassus, Aimard, & Trillet, 1992; McFarland & Fortin, 1982; Murayama, Kashiwagi, Kashiwagi, & Mimura, 2004; Russell & Golfinos, 2003; Terao et al., 2006). Hemispheric specialisation for speaking and singing has also been suggested by functional brain imaging which shows increased activation in right-hemispheric brain areas during singing as compared to speaking (Callan et al., 2006; Jeffries et al., 2003; Ozdemir, Norton, & Schlaug, 2006; Riecker, Ackermann, Wildgruber, Dogil, & Grodd, 2000).

In contrast to these assumptions, other authors suggested that word production is based on the same brain mechanisms regardless of whether words are sung or spoken (Hebert et al., 2003; Peretz, Gagnon, Hebert, & Macoir, 2004). The improved performance during singing, as compared to speaking, might depend on several factors such as easier and more fluent articulation (Colcord & Adams, 1979), or singing with auditory models such as choral singing (Racette, Bard, & Peretz, 2006). Improved production of word phrases, at least in the case of familiar songs, might be due to the tight connection between words and music in long-term memory (Baur, Uttner, Ilmberger, Fesl, & Mai, 2000; Crowder et al., 1990; Hebert & Peretz, 2001; Peretz, Radeau, & Arguin, 2004; Samson & Zatorre, 1991). The latter perspective suggests that the musical part of familiar songs helps to produce words. However, the words which are sung are represented by the same brain areas as the spoken words (Hebert et al., 2003; Peretz, Gagnon, et al., 2004). Furthermore, familiar songs are over-learned and coupled with automatic motor programs, which facilitate the production of stored word strings (Wallace, 1994). Taken together, when controlling for other factors, singing should not have any effect on word production (Hebert et al., 2003).

There are only few studies, which have investigated the question of how music facilitates speech under controlled experimental conditions. Cohen and Ford (1995) found no evidence to assume that music facilitates phrase production in aphasic patients. Performance of familiar song lyrics was investigated under three experimental conditions: lyrics spoken naturally (without any support), lyrics recited to the accompaniment of a steady drumbeat and lyrics sung accompanied by the correct melody on keyboard.

Word intelligibility was surprisingly increased under natural speech conditions, as compared to the other two conditions. These outcomes might be due to the specific, rather difficult conditions of song reproduction. Furthermore, the musical abilities of patients were not reported in this study, allowing for the possibility that patients' musical capacities were also strongly impaired. In contrast to these findings, a single case study of a non-fluent aphasic singer (Wilson, Parsons, & Reutens, 2006), found a beneficial effect of melodic intonation therapy on word production, especially in the long term. This effect was suggested to rely on the association between music and text in long-term memory. Recent single case studies (Hebert et al., 2003; Peretz, Gagnon, et al., 2004) and a recent study of eight patients with different speech disorders (Racette et al., 2006) investigated subjects who suffered from expressive aphasia, yet had widely preserved singing abilities. The single case study

patients were still able to sing familiar songs despite an inability to speak the song lyrics under free recall conditions. This effect was not seen in the study of Racette et al. (2006). Furthermore, to investigate word production under controlled conditions, repetition tasks were used in all three studies. Patients were requested to repeat lyric excerpts from familiar and unfamiliar songs under two different conditions; singing and speaking. With the exception of one condition during which the aphasics sung along with an auditory model (Racette et al., 2006), the number of reproduced words did not differ significantly between singing and speaking conditions in any of the experiments conducted. The authors concluded that these studies do not support the assumption that singing helps word production in non-fluent aphasics, even with familiar songs. Word production seems to be based on the same brain mechanisms regardless of whether words are spoken or sung.

Thus, none of the previous studies found any evidence to suggest that aphasic patients can sing phrases from familiar or unfamiliar song lyrics any better than they can speak them under phrase repetition conditions. We reinvestigated this question here, with the help of a non-fluent aphasic patient who was severely impaired, with almost complete loss of the left hemisphere. He was reportedly more able to sing than speak. In contrast to previous studies, this patient showed pronounced improved phrase production while singing familiar lyrics as compared to reciting these lyrics under repetition conditions. In subsequent experiments, we tried to find out whether this phenomenon was based on singing conditions or whether it was specific to familiar songs. We investigated whether unfamiliar song melodies, freely generated melodies or well-learned melodies, which had no previous association to any text, might support phrase production.

2. Methods

2.1. Subjects

Single case GS. To identify suitable patients, we searched for severely affected aphasic subjects who were described by their relatives as musical with an ability to sing whilst simultaneously widely unable to generate speech. Furthermore, patients should have sufficient speech comprehension to understand the experimental tasks. Patients were identified within a research project for aphasics running in the Department of Biological and Clinical Psychology at the Friedrich Schiller University Jena (FSU) (Dilger et al., 2006; Richter et al., under review), through other scientific institutes and medical centres within and outside the FSU and by self-help groups. Lastly, one non-fluent aphasic patient was identified who matched the inclusion criteria and was motivated to participate in the current research project. The patient GS was a right-handed German speaking 56-year-old male who, prior to his illness, had worked as an officer at the tax office. He suffered from non-fluent aphasia resulting in an almost complete inability to generate speech spontaneously. He could only articulate few words very slowly. His speech comprehension was far better than his speech production and he was clearly able to understand the experimental tasks. GS was tested with a common German aphasia test battery, the "Aachener Aphasia Test" (AAT; Huber, Poeck, Weniger, & Willmes, 1983). The results provided in Table 1 indicate that GS had difficulties with every test, including word repetition. However, in contrast to the other subtests, speech comprehension was less affected. Thus, the primary impairment of GS is the generation of purposeful, propositional speech. In addition to this, problems were also illustrated during word repetition. Analysis of his phrase production during the experiments did not indicate clear signs of speech apraxia. There were no typical searching

Table 1
GS' performance in speech, music and neuropsychological assessment

Test	Test score
Aachener Aphasia Test (AAT) ^a	
Token Test	21
Repetition	41
Writing	24
Naming	39
Comprehension	58
Montreal Battery of Evaluation of Amusia (MBEA) ^b	
Scale	26
Contour	20*
Interval	20*
Rhythm	24
Meter	17*
Memory	19*
Average across tasks	21*
Test Battery for Attention Performance (TAP) ^c	
Alertness without warning	16
Alertness with warning	2
Divided attention (all)	<1
Go/Nogo	2
Neglect-Test (left)	8
Neglect-Test (right)	14
Benton Test ^d	5

^a Percentile ranks compared to a normative sample of aphasics.

^b Number of correct responses (*below cut-off score which corresponds to 2 S.D. below mean value of healthy subjects).

^c Percentile ranks (reaction times) compared to a normative sample of age-matched healthy subjects.

^d Number of correct responses (norm value: 7).

movements during speech. GS showed no groping articulation, and no variable attempts to articulate a word. Words were produced relatively fluently or, not at all (see also Section 4). He showed signs of a mild dysarthria. GS' articulation was rhotic, which is uncommon in standard-German. Labio-dental phones (German: [w]) were consistently spoken more rounded, which is also uncommon in standard-German. The patient's articulation did not improve when singing, as he made the same typical errors during both the speaking and the singing condition. GS was able to sing familiar songs and actually he still sings sometimes in the church and at home. As a young man, he sang in a choir and played trumpet in a dance orchestra for 10 years. GS received some formal music training when he learned to play trumpet and was therefore able to read music. As a young man, he also received formal music training while singing in the choir. Since the experimental results revealed some difficulties in music production, we tested music perception and memory in an additional examination. GS was tested with the Montreal Battery of Evaluation of Amusia (Peretz, Champod, & Hyde, 2003). Results provided in Table 1, indicate that GS scored below the cut-off in four out of six tests, especially in the more difficult tests. Thus, problems in music perception and memory may have partially contributed to his difficulty to correctly solve the tasks.

GS suffered from left-hemispheric stroke of the cerebral medial artery. His stroke occurred in 1997, 7 years prior to the start of this study. The hemispheric lesions induced by this stroke were confirmed by recording a high-resolution T1-weighted anatomical volume (192 slices, TE = 5 ms, matrix = 256 mm × 256 mm, resolution = 1 mm × 1 mm × 1 mm; duration = 12 min) with a 1.5T magnetic resonance scanner ("Magnetom Vision plus", Siemens, Medical Systems, Erlangen, Germany). Analysis of this anatomical data confirmed a lesion which almost completely involved the left hemisphere (Fig. 1). Only parts of GS' occipital cortex, inferior temporal cortex, and medial prefrontal cortex were preserved. The cerebellum was also preserved. Furthermore, due to malign brain oedema, a decompressive craniotomy was conducted in 1998, which led to partial skull destruction (see Fig. 1). GS also suffered from right facial paresis and paresis of the right upper and lower extremities. He was well oriented and had no history of psychiatric

or additional neurological disorders. Standard neuropsychological tests [Subtests (alertness with and without warning, divided attention, Go/Nogo, and neglect-test) of the Test Battery for Attention Performance (TAP, Zimmermann & Fimm, 1993); Benton Test (Benton, 1996)] revealed impairments in attention and immediate visual memory (see Table 1).

Control subjects. We also recruited four healthy control subjects (two males, two females) who were of similar age to GS (mean: 65.3 years; range: 49–74 years). All control subjects liked to sing and three control subjects actually sang in a choir.

All subjects provided informed consent to participate in the study. The experimental procedures were approved by the Ethics Committee of the FSU and the investigation was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

3. Materials and methods

Several of the procedures in this study were widely adopted from previous studies (Hebert et al., 2003; Peretz, Gagnon, et al., 2004; Racette et al., 2006). Subjects were presented with excerpts from familiar (experiment 1) and unfamiliar songs [experiment 2 and experiment 3 (only conducted with GS; see below)]. Each song excerpt was firstly sung or spoken by the experimenter, subjects were then immediately requested to repeat the phrases. The experimental sessions were recorded using a portable cassette recorder. Two musically trained raters evaluated both the text and the melody production. Inter-rater agreement was high (for all experimental conditions >94%). Words and notes rated differently by both raters were discarded from analysis. The exact proportion of discarded words was 2.4% (singing, experiment 1), 0% (speaking, experiment 1), 5.1% (singing with freely generated melody, experiment 2), 5.6% (singing with matched melody, experiment 2), 5.1% (speaking, experiment 2), and 0% (singing and speaking, experiment 3). The exact proportion of discarded notes was 3.1% (singing with "la", experiment 1) and 0% for all other conditions. The percentage of correctly repeated words and notes was calculated for text and music. Words were scored as incorrect when one of the following errors occurred: phonemic errors (including omissions of phonemes), lexical errors, omissions (of syllables or words), inversions, additions, or neologisms/unintelligible. Music was regarded as incorrect when notes were out-of-tune, missing or when extra notes were added. In addition, in the rare cases that notes were not out-of-tune but associated with a clear violation of time interval between notes, these errors were also coded. Most errors were due to notes being omitted or wrong pitch. Performance data was analysed using the Fisher non-parametric exact test, which also allows data analysis for small numbers of observations under any experimental condition. Due to multiple testing, a conservative probability level of $p < 0.01$ was considered statistically significant.

3.1. Experiment 1: familiar song production

In experiment 1, performance of familiar songs was tested. Fifty-two children songs and traditional songs were selected (Rilz & Rettich, 2002; Rölleke, 1993). Prior to the experiment, GS rated whether or not he was familiar with these songs. Thirty-two excerpts were then taken from the 38 songs which were familiar to him. The subjects were presented with 16 different song excerpts per condition. Selection of excerpts used in testing aimed, as far as possible, to generate semantically and syntactically complete phrases. Excerpts were randomly assigned to two different experimental conditions: (1) excerpts to be sung by subjects and (2) excerpts to be spoken by subjects. For the speech condition, excerpts comprised of 5.1 words on average (range: 4–6). For the singing condition, there were 5.0 words on average (range: 4–7) and 7.8 notes (range: 7–11). There were four blocks with four phrases per condition. Order of blocks (including short breaks) was as follows: singing, speaking, break, singing, speaking, break, speaking, singing, break, speaking, singing. At the end of this experimental session, 16 randomly selected song melodies (7.0 notes on average, range: 4–11) on the syllable "la", were presented to test music production in isolation.

3.2. Experiment 2: unfamiliar song production

Twenty unfamiliar songs were selected from German-speaking singer-songwriters who were supposedly unknown to the older partici-

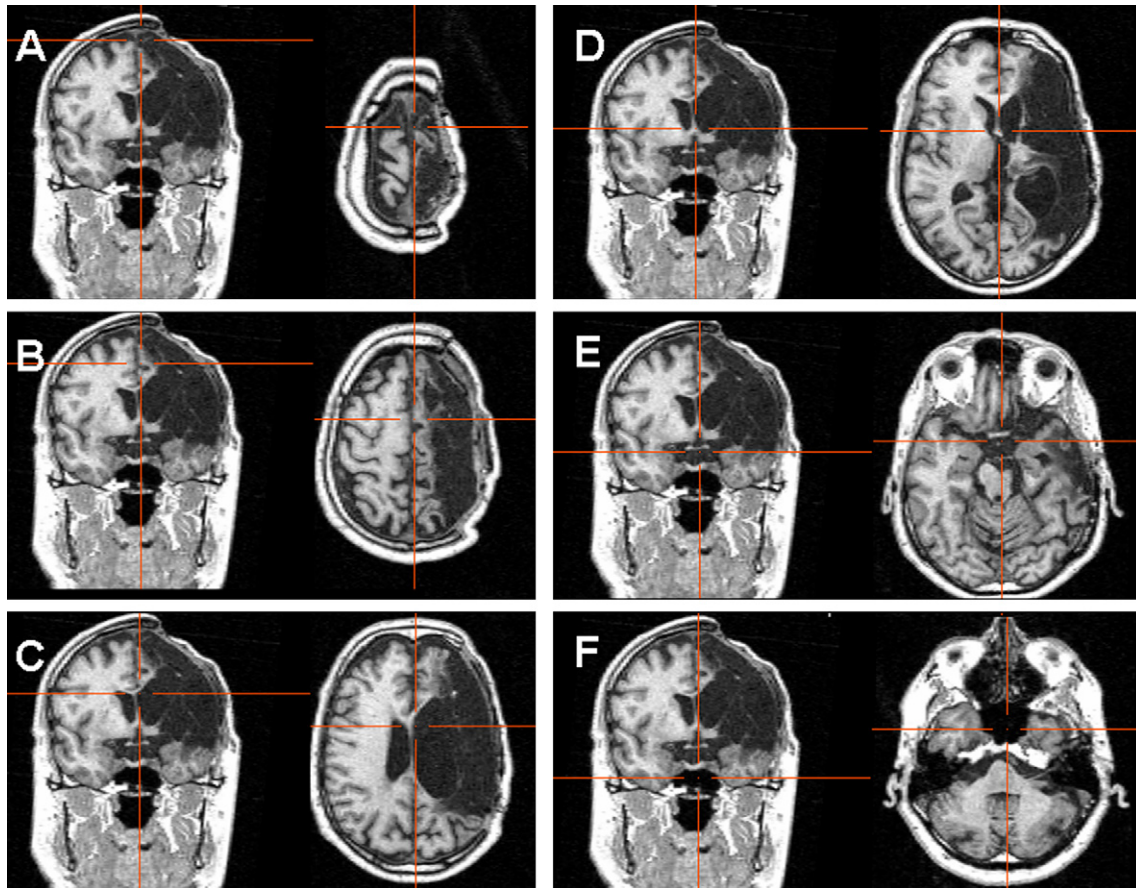


Fig. 1. Anatomical scan of GS' brain. Transversal slices are shown in steps of 20 mm (from A to F). The cross shown in the coronal slice indicates the position of the transversal slice.

pants. Indeed, subjects confirmed prior to the experiment that these songs were unknown to them. From these 20 unfamiliar songs, 48 phrases were selected with easy semantic content, comparable to familiar songs, and easy syntactic structure (e.g., no foreign words, no composites with more than three syllables). Selection of excerpts used in testing aimed, as far as possible, to generate semantically and syntactically complete phrases. Song excerpts were randomly assigned to the different experimental conditions. As in the previous experiment, subjects had to repeat each excerpt under singing and speaking conditions. There was one additional condition, which required subjects to choose any melody to produce the words. This condition tested whether an advantage of automatic or unrestricted melodic production for the repetition of words might exist. Excerpts were on average 5.1 words (range: 3–6) for the speaking condition (SP), 5.3 words (range: 4–7) for the “singing with freely generated melody” condition (SIF), and 5.8 words (range: 3–8) and 8.3 notes (range: 6–11) for the “singing with matched melody” condition (SIM). There were four blocks with four phrases per condition. Order of blocks (including short breaks) was as follows: SIM, SIF, SP, break, SIF, SIM, SP, break, SP, SIF, SIM, break, SP, SIM, SIF. At the end of this experimental session, 16 randomly selected melodies from unfamiliar songs were presented on the syllable “la” (7.3 notes on average; range: 4–10) to test music production in isolation.

3.3. Experiment 3: phrase production with novel learned melody

This experiment was solely conducted with GS in an additional session and not with the control subjects. Two weeks before this experiment, GS received a cassette with a melody sung by the experimenter on the syllable “la”. The melody had an easy structure comparable to melodies used in the melodic intonation therapy (Albert, Sparks, & Helm, 1973). The stepwise melody consisted of eight notes within a fourth as indicated in Fig. 2. This experiment aimed to reduce the cognitive load induced by the need to reproduce novel melodies (see

experiment 2). We asked whether the use of an over-learned, easy melody, which had no association to any text, might improve the production of the text sung with this melody. Using a melody not previously associated with lyrics, we avoided mismatching familiar song melodies (associated with the corresponding familiar text) and, thus, possible interference effects.

We tested whether the melody could be reproduced on the syllable “la” immediately prior to the phrase production examination. GS sang this melody



Fig. 2. Text and melody examples. (A) Melody and text of a familiar song phrase. The English translation of the lyrics is *Fox, you have stolen the goose*. (B) Melody and text of an unfamiliar song phrase. The English translation of the lyrics is *Hey, little girl on the bicycle*. (C) Melody of experiment 3 with text example. The English translation of the lyrics is *Now, spring is here again*.

Table 2
Results for experiment 1: familiar songs (% correct)

Variable/condition	GS	Control group
Word production		
Singing	58.8	99.7 (range: 98.8–100)
Speaking	30.5	100
Notes production		
Singing	93.4	99.8 (range: 99.2–100)
Singing with “la”	67.6	98.5 (range: 95.7–100)

perfectly (100% correct; see Section 4). During the experiment, the melody was combined with 32 excerpts from unfamiliar songs, which were described in experiment 2. There were two experimental conditions: (1) excerpts, which should be sung, and (2) excerpts, which should be spoken. There were 16 different song texts per condition. Song excerpts were randomly assigned to the different experimental conditions. Excerpts comprised of an average of 5.1 words for the speech condition (range: 3–6) and an average of 6.0 words for the singing condition (range: 4–7). There were four blocks of four phrases per condition. Order of blocks (including short breaks) was as follows: singing, speaking, break, singing, speaking, break, speaking, singing, break, speaking, singing.

4. Results

4.1. Experiment 1: familiar song production

GS' performance data showed a significant difference in phrase production between singing and speaking conditions. Although only 30.5% of the words were repeated during the speaking condition, he nevertheless produced 58.8% of correct words during the singing condition ($p < .001$). This finding was not due to effects of condition order, as the results were essentially the same regardless of which part of the experiment (first or second half) was examined. There were 60.0% vs. 32.6% correct words ($p < .05$) for singing vs. speaking in the first half, and 57.1% vs. 28.2% correct words ($p < .05$) for singing vs. speaking in the second half of the experiment. GS' performance was worse than the control group (98.8–100% correctly reproduced words) under both conditions (see Table 2). In the control group, there were no significant differences in correctly reproduced words between conditions. Analysis of errors during phrase production showed that GS mainly made omissions (79% of all errors during singing and 100% of all errors during speaking; see Table 4). Words were omitted in almost all of these cases (92.3% of all omissions during singing and 100% of all omissions during speaking). Analysis of music production by GS revealed a significant difference between the “singing with words” and the “singing with “la” condition. He produced more correct notes under the “singing with words” (93.4%) than under the “singing with “la” (67.6%) condition ($p < .001$). He showed a performance, which was inferior to control subjects under both conditions (range across conditions: 95.7–100% correct notes). However, under the “singing with words” condition, production of the correct notes was nearly comparable with the performance of the control subjects (see Table 2). Reproduction of both notes and additionally words, was obviously enhanced when both parts of familiar songs were simultaneously produced. There were no significant differ-

Table 3
Results of experiment 2: unfamiliar songs (% correct)

Variable/condition	GS	Control group
Word production		
Singing (original m.)	8.3	98.4 (range: 95.7–100)
Singing (self-generated m.)	24.3	97.9 (range: 94.1–100)
Speaking	20.0	98.8 (range: 97.6–100)
Notes production		
Singing (original m.)	5.3	84.5 (range: 72.9–100)
Singing with “la”	47.4	82.6 (range: 71.4–99.2)

m = melody.

ences in musical production between conditions in the control group.

4.2. Experiment 2: unfamiliar song production

In this experiment, no significant effect of experimental conditions on phrase production was found in the patient. GS performed poorly under all three conditions. As a tendency, his most impaired phrase production was evident during the singing condition, i.e., when he had to reproduce text and melody simultaneously (8.3% correct words). Control subjects showed a range of 95.7–100% correct words (see Table 3). GS produced 20% of correct words under the speaking condition, while control subjects in all cases showed a performance within a range of 98.8–100% correct words (see Table 3). GS was unable to use a melody for phrase production in the condition which allowed a self-generated melody. Instead, he attempted to speak the words in each trial (24.3% correct words; Table 3). This effect was evident, although GS was able to sing freely chosen melodies on the syllable “la” (not quantitatively assessed). Under this condition, control subjects used self-chosen melodies in all cases, which had no impact on phrase production (range: 94.1–100% correct words; see Table 3). There were no significant differences in correctly reproduced words between conditions in the control group. Analysis of errors during phrase production showed that GS mainly made omissions (98% of all errors during “singing with matched melody”, 84% of all errors during “singing with self-generated melody”, and 83% of all errors during speaking; see Table 4). In almost all cases words were omitted (>93.0% of omissions regardless of condition).

Analysis of GS' music production revealed a significant difference between the “singing with words” condition and the “singing with “la” condition. He produced less correct notes under the “singing with words” than under the “singing with “la” condition (5.3% vs. 47.4%; $p < .001$; Table 3). Under both conditions, he showed an inferior performance as compared to control subjects (range across conditions: 82.6–100% correct notes; Table 3). However, one has to consider that the percentage of correct notes produced by GS strongly depended upon phrase production, as word omissions were also scored as note omissions and therefore as errors in music production. Thus, under the “singing with matched melody” condition, he was, in most cases, unable to produce anything. There were no signifi-

cant differences in music production between conditions in the control group.

4.3. Experiment 3: phrase production with novel learned melody

In the third experiment, GS had learned a novel melody on the syllable “la”. Before the experiment began, we examined GS to see if he could reproduce the melody. He repeated each note perfectly (100% correct). This melody was then presented together with unfamiliar lyrics. However, GS was unable to use the melody to reproduce the lyrics. Under the “singing with words” condition, he produced no correct words (0% correct), since he only tried to sing the melody. He produced 91.8% correct notes during this condition. Under the speaking condition, he produced 20.0% correct words, which is comparable to his performance under the speaking condition in experiment 2 (also 20.0% correct). In experiment 3, performance during speaking was significantly better than during singing ($p < .001$). This effect was seen regardless of which part of the experiment (first or second half) was examined (17.0% correct words in the first and 24.4% correct words in the second half; both $p < .05$ compared to singing).

Analysis of errors in phrase production showed that GS did not produce intelligible words under the singing condition (all errors were omissions of words; he always sang the melody on the syllable “la”). He mainly showed omissions (75% of all errors) under the speaking condition (see Table 4). Words were omitted in almost all cases (93.9% of all omissions).

5. Discussion

We investigated the production of word phrases, which were sung and spoken by a severely affected, non-fluent aphasic patient under controlled repetition conditions. The main finding was a pronounced dissociation between singing and speaking familiar song lyrics. However, the outcomes of further experiments illustrate that the superior performance during singing, compared to speaking familiar lyrics, cannot be explained by the effect of singing word phrases. A memory-based mechanism seems to be the most likely explanation for this effect.

Table 4
Errors in GS’ word production in all experiments (% of all errors per condition)

Experiment/condition	P	L	O	A	I	N
Experiment 1						
Singing	33	–	67	–	–	–
Speaking	–	–	80	10	–	10
Experiment 2						
Singing (original m.)	1	1	98	–	–	–
Singing (self-generated m.)	6	8	84	–	–	2
Speaking	10	5	83	2	–	–
Experiment 3						
Singing	–	–	100	–	–	–
Speaking	19	3	75	3	–	–

P = phonemic errors; L = lexical error; O = omissions, A = additions, I = inversions, N = neologisms/unintelligible.

The dissociation which is evident between GS’ between singing and reciting familiar song lyrics stands in contrast to the results of previous studies (Hebert et al., 2003; Peretz, Gagnon, et al., 2004; Racette et al., 2006). Thus, the advantage aphasic patients have when singing as compared to speaking the words from familiar lyrics is a limited phenomenon, at least under controlled repetition conditions. However, under less restricted conditions it has been shown that many patients are able to sing songs although they are unable to speak the lyrics (Amaducci et al., 2002; Hebert et al., 2003; Jacome, 1984; Smith, 1966; Sparks et al., 1974; Warren et al., 2003; Yamadori et al., 1977). Repetition tasks, as used in this study and in other studies, are a special experimental condition. Many non-fluent aphasics perform relatively well in such tasks (as did most patients in comparable previous studies). High performance under word phrase repetition conditions limits the chances to detect further improvements while singing due to ceiling effects.

In this study, GS showed a performance of about 20–30% correctly reproduced words under speaking conditions, from familiar and unfamiliar song lyrics. Thus, this patient had a relatively inferior performance in the word phrase repetition tasks. GS exhibited a marked improvement in phrase production while singing familiar songs, which resulted in almost 60% correct words. This effect was not evident for unfamiliar songs presented with their original melodies. Furthermore, the option to self-generated melodies did not help with the production of unfamiliar text. Most importantly, there was also no support for phrase production when the unfamiliar text was coupled with an overlearned and easy melody. GS only tried to reproduce the melody, however, he was unable to combine both the text and music.

The finding that singing of unfamiliar words did not improve phrase production is in accordance with previous studies (Hebert et al., 2003; Peretz, Gagnon, et al., 2004; Racette et al., 2006). Compared to previous studies, in this study we used tasks that allowed an additional examination of the effects of singing conditions on phrase production. The utilization of a freely generated melody tested whether spontaneous melodic intonation might be helpful for word repetition. Furthermore, using a melody, which was well known and not text-associated, reduced cognitive demands as compared to previous studies, which mismatched familiar melodies with familiar song lyrics. Even with these additional conditions, a helpful effect of singing on phrase production was not seen. This might partially be due to the impairments of this patient in music perception and memory. Furthermore, one could argue that the singing condition in experiment 3 was still coupled to an interference effect imposed by the association between the tune and the syllable “la”. Thus, the patient might not have only reproduced an overlearned melody, but also the corresponding overlearned articulatory motor patterns. However, the syllable “la” is neutral in the sense that no lexical association is given. Furthermore, the syllable “la” is often typically used to learn new melodies. Normally, one can switch easily between “la” and words when reproducing songs. GS also used “la”, “da”, or simply hummed to continue melodies when he could not reproduce the words. We believe that the patient was highly motivated to reproduce the learned

melody correctly and was therefore unable to combine music and text.

GS also showed a remarkably greater ability to produce familiar music when both words and music from familiar songs had to be simultaneously presented, as compared to the “singing with ‘la’” condition. This illustrates, on the one hand, that GS had some difficulties repeating melodies. These difficulties might partially be based on a general impairment in his perception and memory of music as indicated by the results of the amusia test battery. On the other hand, this effect also suggests that either part of the song (melody or text) helps to produce, or at least to remember, the other part of familiar songs (Baur et al., 2000; Crowder et al., 1990; Steinke et al., 2001; Terao et al., 2006).

The most likely conclusion is that the effects found for familiar songs are based on the tight connection between text and music in long-term memory. Several authors (Hebert et al., 2003; Peretz, Gagnon, et al., 2004; Samson & Zatorre, 1991; Wilson et al., 2006) have suggested that memory processes might be of specific importance for the understanding of superior singing performance in aphasics. Music might support speech production, due to a better access to lexical and/or articulatory representation of words, since it is the musical aspect of a song which serves as an additional retrieval cue. From the neuroscientific perspective, phrase production might depend on the same brain areas, regardless of whether words are sung or spoken (Hebert & Peretz, 2001; Peretz, Gagnon, et al., 2004). The neural representation of words would be more easily accessed during singing, as compared to speaking, due to afferent input by areas representing the musical part of the songs. However, it may also be possible that lyrics which are sung, are represented differentially, as compared to spoken lyrics (Samson & Zatorre, 1991). From this perspective, superior performance during singing might be based on preserved neural circuitries, which are responsible for storage and production of familiar songs. Musical and verbal components of songs would be integrated in neural stores instead of being neuroanatomically separated (but see Hebert & Peretz, 2001; Peretz, Radeau, et al., 2004). In addition, familiar songs are overlearned and coupled to automatic motor programs, which facilitate the production of stored word strings (Wallace, 1994). Such automatic motor programs representing procedural memory and non-propositional speech seem to be – in contrast to the generation of propositional, purposeful speech – at least in part independent of left-hemispheric cortical areas. Automatic song production seems, for example, to depend on right basal ganglia (Speedie, Wertman, Ta’ir, & Heilman, 1993).

Our study cannot answer the question which concerns the type of memory process responsible for GS’ improved phrase production when singing familiar songs. The different possible memory effects are not mutually exclusive. Due to his immense lesion, GS had lost almost his entire left hemisphere, suggesting a strong involvement of the right hemisphere when singing familiar lyrics. Thus, this case supports previous lesion (e.g., Amaducci et al., 2002; Bautista & Campetti, 2003; Confavreux et al., 1992; McFarland & Fortin, 1982; Murayama et al., 2004; Russell & Golfinos, 2003; Terao et al., 2006; Smith, 1966; Warren et al., 2003; Yamadori et al., 1977) and functional imag-

ing studies (e.g., Callan et al., 2006; Jeffries et al., 2003; Ozdemir et al., 2006; Riecker et al., 2000) which proposed a specific function of the right hemisphere during singing.

Our results also allow the conclusion that a piece of text may be represented, together with a melody, in long-term memory, if it constitutes part of the lyrics of a familiar song. Thus, our data are compatible with the idea of a song store. Activation of this store leads to increased reproduction of both the text and the melody of a song. This option seems more likely than to assume an association between the melody and the lexical representation of each word, since the word itself is only associated with some tones in a melody. However, the melody might help to produce words within word strings. Furthermore, overlearned, automatic melodic speech might contribute to GS’ performance, since this seems to be a right-hemispheric phenomenon. The fact that the patient’s articulation did not improve during singing stands in some contrast to this idea. However, one has to consider that in many dysarthric patients, the speech errors occur constantly across different forms of voluntary and involuntary (automatic) speech.

It must be noted that the patient had problems in executive functions and memory. Although problems in repetition do not necessarily indicate problems in verbal working memory, it is clear that, given his immense lesion, the patient had deficits in verbal short-term memory. The patient had probably problems to chunk the four to six words of the test items. In familiar songs, the melodies may have contributed to a chunking of the words of the lyrics, and thereby helped to memorize and reproduce the phrases.

Future studies should also test whether learning text and melody together is a better strategy for word repetition than learning only the text or the melody. A very recent study by Wilson et al. (2006) suggested that, in the long-term, the combined rehearsal of words and melodies in melodic intonation therapy has a beneficial effect on phrase production, as compared to rehearsing non-melodic word phrases. The study of Wilson et al. first presented evidence to show that even melodic text phrases learned extensively after the brain lesion seem to facilitate the number of intelligible words in phrase production, due to a long-term memory effect which allows better access to words with the help of music.

To conclude, this study presents a non-fluent aphasia case, which shows a clear dissociation between singing and speaking familiar song lyrics under repetition conditions. A superior performance during singing as compared to speaking was not seen for novel song lyrics, regardless of whether these were coupled with an unfamiliar, a familiar, or a spontaneously generated melody during the singing conditions. These findings propose that singing may help phrase production in some specific cases of severe expressive aphasia, even under very controlled experimental conditions. However, the association of melody and text in long-term memory seems to be responsible for this effect.

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