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Singing in the Brain: Insights from Cognitive Neuropsychology

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Singing abilities are rarely examined despite the fact that their study represents one of the richest sources of information regarding how music is processed in the brain. In particular, the analysis of singing performance in brain-damaged patients provides key information regarding the autonomy of music processing relative to language processing. Here, we review the relevant literature, mostly on the perception and memory of text and tunes in songs, and we illustrate how lyrics can be distinguished from melody in singing, in the case of brain damage. We report a new case: G.D. has a severe speech disorder, marked by phonemic errors and stuttering, without a concomitant musical disorder. G.D. was found to produce as few intelligible words in speaking as in singing familiar songs. Singing "la, la, la" was intact and hence could not account for the speech deficit observed in singing. The results indicate that verbal production, be it sung or spoken, is mediated by the same (impaired) language output system and that this speech route is distinct from the (spared) melodic route. In sum, we provide here further evidence that the autonomy of music and language processing extends to production tasks. This literature review bears on the issue of the separability of text and melody in songs in general, with a particular emphasis upon evidence from cognitive neuropsychology.

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Singing constitutes the most widespread mode of musical expression. All individuals across cultures have taken part in singing in some form. This pleasurable experience is most likely rooted in the early exposure to maternal singing, which is swiftly imitated by the infant. Infants spontaneously sing around the age of 1 year old. At 18 months, the child begins to generate recognizable, repeatable songs (Ostwald, 1973). These spontaneous songs have a systematic form and display two essential features of adult singing: they use discrete pitches, and they use the repetition of rhythmic and melodic contours. They are unlike adult songs, however, because they lack a stable pitch framework (Dowling, 1984). It is later, around the age of five, that children appear to hold a stable tonality and a regular beat as adults do (Dowling & Harwood, 1986). Thus, by the age of five, children have a fairly large repertoire of songs of their own culture and display singing abilities that will remain qualitatively unchanged in adulthood, unless the child receives musical tutoring or is regularly practicing in a choir or ensemble. Thus, even without much practice, the ordinary adult seems to be endowed with the basic abilities that are necessary to sing simple songs of their culture.

Despite their ubiquity and early acquisition, the singing abilities of ordinary people are rarely studied. The major reason for this limited attention is that singing abilities are considered to be unequally distributed in the general population. This biased point of view is related to the frequent observation that some people sing out of tune in Western cultures. Nevertheless, the few studies in which song production has been examined in the general population have yielded a different conclusion. Nonmusicians are highly consistent in their ability to sing familiar songs. They exhibit precise memory for both pitch level and tempo (Halpern, 1988, 1989). This precision in singing seems to hold not only for a given singer, by measuring individual stability across song renditions (Halpern,1988, 1989; Bergeson & Trehub, 2002), but also for a group of singers, when measuring consistency across individuals in the sung recall of a popular song (Levitin, 1994; Levitin & Cook, 1996). Therefore, as far as singing a familiar song is concerned, heterogeneity in singing abilities does not seem to be a serious limitation. Moreover, an easy solution to circumvent the problem of variability across ordinary singers is to use the singer as his/her own control, as done in Halpern's study and the study by Bergeson and Trehub.

This research strategy, which is centered on individual performance, is typical of cognitive neuropsychology. Typically, the study of a neurologically impaired individual employs a within-subject design, because the homogeneity of the disorders experienced by different brain-damaged patients cannot be assumed a priori (McCloskey, 1993). In fact, any cognitive function, such as singing, consists of numerous processing components and pathways of communication, each of which may be damaged as a conse-

quence of a brain injury. More concretely, in our model of music processing derived from the study of neurologically impaired individuals (Peretz & Coltheart, 2003), there are 12 individuated processing components and 20 pathways. This amounts to 32 components. Thus, as pointed out by Coltheart (2003), there are 2^{32} ways that the system may be damaged. All but one of these ways may correspond to a brain-damaged patient (the one pattern that does not correspond is where all components are intact). Since 2^{32} is a very large number, the probability of coming across two patients with exactly the same musical impairment is very unlikely. Each patient may be unique. Therefore, averaging across groups of patients cannot be justified in this case. Instead, each patient must be investigated and his/her data must be reported on an individual basis. This is why research in cognitive neuropsychology usually takes the form of detailed case studies of individuals with cognitive disorders.

Single case studies are no less valid than group studies. Valid inferences on the functioning of normal abilities can be drawn from the study of single cases, provided that careful consideration of the patient's background and sufficient data are collected and analyzed under controlled conditions. Data from just one case are sufficient to falsify a theory. In this article, we illustrate this point by showing how a single case study conducted in the tradition of cognitive neuropsychology can be informative regarding the normal functional organization of singing abilities. The secondary objective is to provide further evidence, through the testing of singing abilities, that music and language are subserved by largely distinct processing systems. To this aim, we will report the pattern of impaired and spared abilities obtained in a novel case of expressive "aphasia without amusia."

Assuming that the reader is not well-versed in neuropsychology, we will first provide a brief review of what is the condition of "aphasia without amusia" and what can be learned from studying such neurological deficits about the processing of language and music in the normal brain. Thereafter, we will review the relevant literature regarding the possibility that singing is not the simple addition of the separate outputs of language and music processing systems. In fact, classical teaching in neurology as well as behavioral studies with normal listeners suggest that, in songs, music and speech are integrated rather than simply aligned with each other.

Aphasia Without Amusia

Aphasia and amusia are generic terms used in neurology to designate disorders of language and music processing, respectively. The condition of aphasia without amusia refers to cases where a brain lesion has impaired the processing of language without interfering with the processing of mu-

sic. One such notorious case is Vissarion Shebalin, who sustained a second vascular hemorrhage in the left hemisphere of the brain at the age of 57. This stroke left him without speech and deaf to the spoken world. While Shebalin could no longer communicate verbally, he continued to teach and to compose until his death, 4 years later. Shebalin was particularly prolific musically despite his vast left hemispheric lesion; he wrote 14 chorales, 2 sonatas, 2 quatuors, 11 songs, and 1 symphony. According to Shostakovitch, one of his peers, Shebalin's music was undistinguishable from what he had composed before his illness (Luria, Tsvetkova, & Futer, 1965). Although Shebalin's case is spectacular, it is not exceptional, given that similar cases have been reported in the literature (Assal, 1973; Basso & Capitani, 1985; Signoret, van Eeckhout, Poncet, & Castaigne, 1987).

The fact that Shebalin was an outstanding musician does not preclude generalization to the brain of ordinary people. Drastic cases of aphasia without amusia have been observed in nonmusicians. The latter may lose their ability to recognize spoken words and yet remain able to recognize music (Godefroy et al., 1995; Laignel-Lavastine & Alajouanine, 1921; Mendez, 2001). Similarly, brain-damaged patients who are afflicted with verbal agnosia (or word deafness), and hence have lost their ability to recognize spoken words, can maintain normal abilities to recognize nonverbal sounds, including music (Metz-Lutz & Dahl, 1984; Takahashi et al., 1992; Yaqub, Gascon, Al-Nosha, & Whitaker, 1988). The existence of such cases of selective sparing of musical abilities, in both musicians and nonmusicians, suggests that the processing of music is not mediated by the same system as the one involved in language.

It could still be argued that music processing is spared because it is computationally less complex, or more primitive, than language. If this were the case, then brain damage that is sufficiently severe to interfere with musical abilities (the simple abilities) should also be detrimental to language abilities (the complex abilities). This account predicts that one will not find individuals in whom brain damage has impaired the ability to process music while sparing the ability to recognize language. Such cases of amusia without aphasia, however, do indeed exist. For example, Isabelle R., whom we have studied in some detail (Peretz, Belleville, & Fontaine, 1997), is an ordinary woman, devoid of special talents, be it musical or linguistic. She was a restaurant manager when, at the age of 28, she underwent successive brain surgeries for the repair of ruptured aneurysms in the left and right middle cerebral arteries. She survived, but with two vast brain lesions invading the auditory cortex bilaterally and extending to the frontal areas on the right side. In this context, it is surprising to note that Isabelle R. is fully functional in language, memory, and intelligence. She even writes poems. Her persisting and major problem concerns music. Isabelle R. can no longer recognize the music that was familiar to her before her brain accident; she cannot relearn the musical corpus because melodies no longer

leave a trace in her memory; finally, she can no longer carry a tune. Isabelle R. regularly practiced these skills before her brain injury, although she never studied music. This condition of "amusia without aphasia" has been known for more than a century (Marin & Perry, 1999). However, solid evidence has been gathered only recently (Ayotte, Peretz, Rousseau, Bard, & Bojanowski, 2000; Griffiths et al., 1997; Peretz et al., 1994; Piccirilli, Sciarma, & Luzzi, 2000; Steinke, Cuddy, & Jakobson, 2001; Wilson & Pressing, 1999).

The major conclusion to be drawn from these neurological cases of selective aphasia and of amusia is that they point to the existence of at least two distinct series of processing modules: one for music and one for speech. Cases such as Shebalin show how the neural circuitries specialized for music can be selectively spared. Conversely, cases like Isabelle R. demonstrate that these music-specific circuitries can be selectively damaged. However, domain-specificity may arise at different levels in the processing of either language or music. There is no need for all processing components to be specialized for their respective domain to account for cases of selective aphasia and amusia. Damage to only one or two pivotal processing components that are specialized for language (or music) may result in a dysfunction of the entire processing system. This is why it is essential to compare music and language processing in identical task conditions in order to be able to specify the processing component that is responsible for the observed dissociation.

Such conditions are ideally met in the processing of text and melody in songs. The tune and the text of a song are typically heard and learned together. Accordingly, they are expected to leave memory traces that are equally familiar and recoverable. Hence, selective disruption of one song component after brain damage would provide evidence that the processing of tune and text recruit distinct mechanisms. Such demonstrations do exist. As alluded to previously, there are several reports of patients who can no longer recognize the melodies (presented without words) of familiar songs. Yet, they are normal at recognizing the corresponding spoken lyrics (Hébert & Peretz, 2001; Peretz, 1996). Similarly, there are individuals who suffer from lifelong difficulties with music and who can recognize the lyrics of familiar songs even though unable to recognize the tune that usually accompanies them (Ayotte, Peretz, & Hyde, 2002). These observations suggest that the recognition of text and tune in songs is mediated by distinct pathways. This division of labor may occur at the perceptual stage or, at a later stage, when making contact with the song representation in memory. The evidence is compatible with both possibilities.

Thus, the available evidence questions, but does not rule out, the possibility that melody and lyrics are integrated in *memory* for songs (Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986). The few researchers who have addressed this question with neurologically

impaired patients have reached mixed results. Samson and Zatorre (1991) have tested song recognition in groups of patients having sustained a unilateral lobectomy for the relief of epilepsy. They found that text recognition was impaired after a left lobectomy. However, they also found that tune recognition depended on the text with which it was originally paired. These findings led the authors to propose that melody would be integrated to lyrics in memory, but that lyrics would benefit from an additional isolated representation. In other words, there would be a dual code for songs in memory: one song record in which melody and lyrics are integrated and another text record in which only the text of the song would be stored.

More recently, Steinke et al. (2001) have discovered a patient with amusia, K.B., whose results also suggest the existence of a special store for songs. They found that the recognition of familiar song melodies (presented without lyrics) could be maintained, whereas the recognition of familiar instrumental music is lost as a consequence of brain damage. This remarkable sparing of song recognition from hearing the melody was attributed to the existence of intact associated representation of the text. However, the results are also compatible with a proposal along the line of Samson and Zatorre. That is, in addition to a song store in which melody and lyrics would be integrated, there would be another store in which only instrumental music is represented. Hence K.B.'s problem would consist in accessing both stores from musical input alone; however, songs would be somewhat spared because they also contain embedded text information. Singing from memory should throw light on this issue. If indeed lyrics and melodies are integrated in memory, K.B., for example, should be able to sing melodies with their accompanying lyrics but not the melodies alone. Unfortunately, K.B.'s singing abilities could not be tested because he was no longer able to sing. Singing songs is the issue to which we now turn.

Is Singing Special ?

A classical teaching in clinical neurology is that nonfluent aphasics can sing words that they cannot pronounce otherwise. This notion goes back to the discovery of aphasia when Broca (1861) first studied his benchmark case of expressive aphasia. Broca observed that the patient (Tan) could pronounce only the word "tan" but was able to produce intelligible words when singing. This description has been reported in several subsequent cases (Assal, Buttet, & Javet, 1977; Smith, 1966; Yamadori, Osumi, Masuhara, & Okubo, 1977). The traditional explanation of this fascinating observation is that there would be two routes to word articulation: a normal language-based route via the left hemisphere of the brain and a singing route via the right hemisphere (Cadalbert, Landis, Regard, & Graves,

1994). This account of word articulation is very similar to Samson and Zatorre's dual-store account of song memory. The singing route would involve the store in which words are embedded in melodies and the language route would involve the store in which words are represented in isolation.

Partial support for the existence of this dual route has been recently obtained with brain imaging techniques (Jeffries, Fritz, & Braun, 2003). Normal participants have been scanned while speaking or singing the words to a familiar song. The results showed an increase in activity during speaking relative to singing in left hemisphere structures (including the classical perisylvian language areas). Relative increases in activity during singing (versus speaking) were observed in the right hemisphere (being maximal in the right anterior superior temporal gyrus and insula). What is unclear is to what extent this latter effect is due to the musical component of the task or to the use of a special route for singing. The study does not allow a conclusion to be drawn on this point because the melodic control condition (singing "la, la, la") was not included in the design.

If there were a special singing route, the examination of singing performance in patients such as Tan, who has Broca's aphasia, should provide the relevant evidence. Unfortunately, all the early studies (Assal et al., 1977; Smith, 1966; Yamadori et al., 1977) are merely descriptive; the reports are not substantiated by quantitative data and do not include adequate control conditions. Furthermore, the only study in which aphasics' production has been quantified does not support the notion of a special singing route for speech (Cohen & Ford, 1995). Aphasic patients were found to produce more, not less, intelligible words when pronouncing the text in a speaking mode than when singing them. However, the evidence is not conclusive. Patients were not screened for type of aphasia or **{AU: OK to substitute "or" for "not"?}** for the presence of amusia. Thus, patients' group performance might be the result of variable perceptual and expressive deficits.

Recently, we revisited this issue with a nonfluent aphasic who did not have any concomitant musical disorder (Hébert, Racette, Gagnon, & Peretz, 2003). We found no support for the idea that singing promotes word intelligibility. The patient, C.C., produced as few intelligible words in speaking as in singing. He made similar errors whether the text was coming from a familiar song or from an unfamiliar one. Singing "la, la, la" was intact in all conditions and hence could not account for the speech deficit observed in singing. Rather, the results indicate that verbal production, be it sung or spoken, is mediated by the same (impaired) language output system and that this speech route is distinct from the (spared) melodic route.

This is not an isolated finding. In this article, we report a new patient with a converging case of nonfluent aphasia (G.D.) who was able to sing accurately but was unable to articulate words in singing any more intelligibly than in speaking.

Case Study

CASE DESCRIPTION

G.D. is a 74-year-old, left-handed man. He is a native speaker of French, has a grade 12 level of education, and worked as an office manager. He had no musical education. He was referred to the Sherbrooke Geriatric University Institute because of cognitive problems, mainly involving language impairments. According to his wife, language problems started about 10 years before his examination. Computed tomography scans obtained in June 1994 and June 1996 revealed symmetric calcifications at the level of the basal ganglia and the cerebellar nuclei, as well as cortical atrophy of the left frontoparietal region. The patient had no history of cerebrovascular accident and was in good health, without medication. Primary progressive aphasia was diagnosed, a frontotemporal form of dementia (see below).

Neuropsychological Assessment

A summary of G.D.'s cognitive functioning is available in Table 1. At the time of testing (April 1997), G.D. presented signs of general cognitive decline, especially in reasoning abilities (executive functions). However, memory and intellectual functions (as assessed by the Raven progressive matrices) were still intact.

TABLE 1
Intelligence and Memory Assessments of G.D. During Testing

Feature Assessed	Score
Memory	
Working memory : digit span (forward)	5
Long term memory : visuoverbal recognition (Signoret, 1991)	
Immediate recall	23/24
Delayed recall	24/24
Praxis	
Gestures	Normal
Copy of Rey figure	23/36 impaired
Visual functions	
Discrimination	10/10
Benton's line orientation test	13/15
Spatial attention test	31/35
Executive functions	
Trail making test	25th percentile (impaired)
Raven progressive matrices	50th percentile

Language Assessment

Language expression was nonfluent. Articulation was preserved but marked by severe stuttering. Stuttering was characterized by repetitions of initial syllables of words, often distorting them (e.g., "animaux" becomes "zaminjo"). Expressive language also contained neologisms (e.g., "bandit" becomes "espiette") and incomplete responses (e.g., "il n'a pas de … et lui aussi"/"he has no . . . and he too"). Automatic speech was correct for digits and months but poor for familiar lyrics of songs due to stuttering and phonemic transformations. G.D.'s speech was both hard to understand and irritating. Comprehension was largely preserved. A summary of G.D.'s language functioning is given in Table 2. His comprehension and repetition difficulties were generally related to sentence length. The more syllables there were in words or words in sentences, the more impaired G.D. was. This length effect was apparent in oral repetition, in reading and in comprehension, hence suggesting a common phonemic output problem. Overall, performance showed a discrepancy between impaired expressive and spared receptive language abilities.

Musical Assessment

G.D.'s singing abilities are intact. When prompted with 35 song titles, G.D. eagerly sang the first line of 26 of them. The melody is remarkably in

TABLE 2
G.D.'s Performance on Language Tests

Tests	Score	Norms, Mean (S.D.)
Expression		
Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983)	7/60	47
MT-86 ß Aphasia Battery (Béland, Lecours, Giroux, & Bois, 1993)		
Automatic speech	1/3	3
Verbal fluency	3 words	23 (5.4)
Repetition	27/30	29 (1)
Oral reading	26/30	29 (0.9)
Oral picture description	3/18	13 (3)
Discrimination and comprehension		
MT-86 ß Aphasia Battery		
Word and sentence picture-matching	35/47	45 (2)
Body-part identification under oral instruction	8/8	8
Token test	22.5/36	29-36
Tasks adapted form the PALPA (Kay, Lesser, & Coltheart, 1992)		
Same-different discrimination	40/40	39 (1.6)
Auditory lexical (word vs. nonword) decision	50/60	57 (3.5)

tune and recognizable. The text is often unintelligible. Sometimes G.D. manages to articulate the first words correctly but then stutters or switches to "la, la, la." A video example can be seen on our web site (www.fas.umontreal.ca/psy/iperetz.html).

In comparison to his preserved singing abilities, G.D.'s receptive musical abilities are slightly impaired. On the Montreal Battery of Evaluation of Amusia (MBEA; Peretz, Champod, & Hyde, 2003), G.D. was found to perform at a lower level than seven matched control subjects (mean: 70 years of age; 13 years of education) on three of six tests. G.D. scored low in the discrimination of pitch contour and interval changes as well as in memory (Table 3). However, some pitch-based discrimination abilities seem to be spared, because G.D. performed in the normal range in the discrimination of melodies differing by a tone that is out of key. Although G.D. has some perceptual difficulties with music, his residual pitch and temporal discrimination abilities seem sufficient to allow recognition of familiar music, which is normal. Note that the recognition of lyrics is normal too, indicating that G.D.'s difficulty with song lyrics is at the output stage.

Summary and Diagnosis

G.D. presented with nonfluent speech marked by phonemic errors and word-finding difficulties along with signs of cognitive decline. This clinical profile, along with the history of progressive worsening and the presence of particular features such as stuttering, impaired repetition, and reading and writing disorders is suggestive of a diagnosis of nonfluent primary pro-

TABLE 3
G.D.'s Performance on Musical Tests

Test	G.D.'s Score	Scores for Matched Control Subjects, Mean (Range)
Singing from memory		
Melody	26/26	
Text	1/26	
Discrimination and memory (MBEA; Peretz et al., 2003)		
Scale	24/30	26.0 (21-29)
Contour	21/30	25.1 (23-27)
Interval	18/30	24.7 (22-27)
Rhythm	26/30	28.9 (27-30)
Meter	24/30	26.7 (21-30)
Incidental memory	18/30	25.4 (22-27)
Familiarity decision		
Instrumental melody	19/20	
Spoken lyrics	18/20	

gressive aphasia, one of the prototypical clinical syndromes of frontotemporal lobar degeneration (Neary et al., 1998).

EXPERIMENTAL INVESTIGATION OF SINGING AND SPEAKING

The first song line of the 30 most familiar songs in Quebec (Peretz, Babai, Lussier, Hebert, & Gagnon, 1995) were either sung with words, sung as "la, la, la," or spoken by the experimenter. G.D. was instructed to repeat the line immediately after hearing it, in the same expressive mode. Upon request, the trial was repeated. G.D. was allowed to make as many attempts as he wished. Therefore, G.D. was tested across several sessions, each time in a single expressive mode. That is, spoken and singing modes of expression were not mixed in a given session so as to avoid mode-switching errors. Indeed, G.D.'s tendency was always to sing, not to speak. Each session was recorded with a Sony tape recorder.

Song lines comprised 10 notes/syllables on average (range, 6-15). As is normally the case, song lyrics were presented at a faster rate when spoken (mean duration: 2257 ms; 3.8 syllables/s) than when sung (mean duration: 4351 ms; 2.4 syllables/s).

All productions were saved in a digital format. G.D.'s performance was highly variable from one repetition attempt to the next, the first attempt frequently being the best one. Therefore, only G.D.'s best performance for each song line in each version was submitted to analyses. Two speech therapists independently scored the text. Two musically trained judges independently scored the melody. For text, the percentage of correctly articulated syllables was calculated instead of words because G.D.'s errors are syllabic. Criteria for considering a syllable as correct were lenient: if one syllable matched the syllable of the original word in any order, it was considered correct. One point was withdrawn for each additional syllable produced. That is, if the total number of syllables exceeded the number of possible syllables by, say, 5 syllables (as in the spoken rendition represented in Figure 1), then this number was subtracted from the number of correctly reproduced syllables (thus, in the example, G.D. produced 5 correct syllables – 5 additional syllables, hence obtaining a score of 0). For melodies, the percentage of correctly repeated notes was computed. Out-of-tune notes were considered as mistakes. One point was withdrawn for each additional note and for rhythmic mistakes.

Results

Interrater agreements were calculated separately for the syllables and notes for each song. For the syllables in the spoken and sung versions, the interrater correlation was $r\ (58) = .95$, $p < .01$. The 20 syllables that were

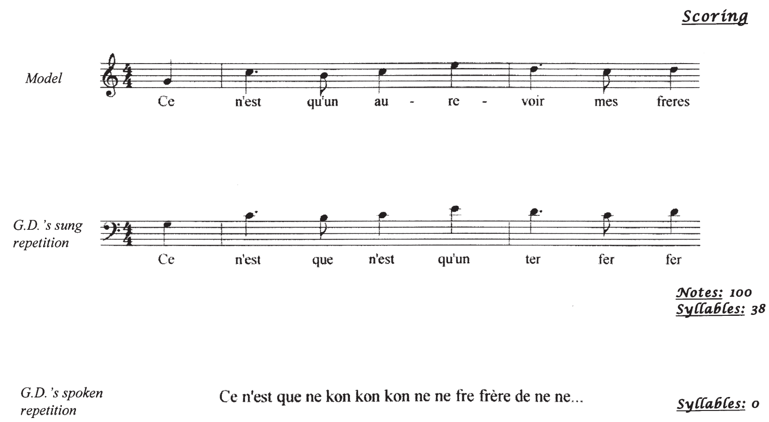

Fig. 1. Notation and scoring of G.D.'s repetition of the first line of the song "Ce n'est qu'un au revoir." The model represents the sung production of the experimenter; Below is the best sung reproduction with words of G.D. and the best spoken reproduction of G.D. The scoring in terms of syllables and notes are presented in percentages. The auditory files can be downloaded from our web site (www.fas.umontreal.ca/psy/iperetz.html).

not rated similarly were discarded from the analysis. For the notes in the sung versions with and without words, the interrater correlation was r (58) = .96, $p < .01$. The 28 notes that were not rated similarly were also discarded from the analysis. The precise numbers of syllables and notes considered in the analysis are presented in Table 4.

The percentage of correctly repeated syllables and notes, for each excerpt in each condition, served as dependent variables. The data (see Table 4) were submitted to an ANOVA taking songs as the random variable, and Component (text vs. melody) and Condition (isolated vs. combined) as within-songs variables. The only effect to reach significance was the song Component, with F (1, 29) = 54.6, $p < .001$, indicating that performance

TABLE 4

G.D.'s Percentage of Correct Note and Syllable Repetition of 30 Beginnings of Familiar Songs Presented in Combination (By Singing) or in Isolation (Spoken or Sung La, La, La)*

Song Presentation	Text	Melody
Combined (sung)	65	93
	(301)	(293)
Isolated	58	96
	(305)	(284)

* Raw numbers in parentheses.

on melody was much higher than performance on text. The slightly superior performance observed in text singing over speaking was far from significant, $t(29) = 1.01$. Thus, singing did not help G.D. to articulate syllables in any systematic fashion, although G.D. tended to produce less supernumerary syllables while singing (with 5%) than speaking (16%; $c^2 = 21.4$, with 1 *d.l.*, {**AU: do you mean d.f. for degree of freedom?**} $p < .001$; see Figure 1). Singing tends to constrain G.D.'s speech. However, the nature of the errors was similar in both expression modes (see Table 5)

In general, G.D.'s speech errors are typical of acquired neurological stuttering disorder. G.D. involuntarily repeated uttered syllables in both singing and speaking, a behavior similar to what was observed in spontaneous speech. G.D. produced similar phonemic errors (e.g., "Au clair de la lune" becomes "Au kair de la lune") and neologisms (e.g., "D'où viens-tu bergère" becomes "D'où viens-tu vieiarchère"), as illustrated in Figure 1 and quantified in Table 5.

CASE DISCUSSION

G.D. has dementia with primary progressive aphasia and preserved musical expression. In the present study, we show that his loss of speech affected speaking and singing in a similar fashion. This observation argues against the notion that singing enhances speech fluency. It also questions the claim that stuttering can be alleviated by singing (Bloodstein, 1995).

G.D.'s spoken and sung production was marked by stuttering, a condition that can be improved by singing. {**AU: do you wish to rephrase the preceding sentence? You just described it as a "claim" at the end of the preceding paragraph, yet state it like a fact in this sentence?**} Singing is usually described as one of the conditions that enhance fluency and word intelligibility in patients with *developmental* stuttering (Healey, Mallard, & Adams, 1976). However, cases of *acquired* stuttering, which occurs as a consequence of brain damage, as in G.D., are less common and the evidence is less clear. Some have reported fluent singing (Horner & Massey, 1983) while some have not (Helm, Butler, & Benson, 1978). The evidence is weakened by the fact that these observations are anecdotal and obtained in poorly controlled conditions. This is not the case with G.D., who suffers from acquired stuttering with intact singing. Therefore, G.D. can be considered as the first documented patient with acquired stuttering

TABLE 5
Speech Error Types in Singing and Speaking Expressed as Percentages

	Repetition	Phonemic	Neologisms
Sung	37	43	20
Spoken	25	71	4

whose speech is examined while singing. As stated previously, this case study does not support the notion that singing improves speech fluency. Rather, it argues for the complete autonomy of speech and music in production.

The idea that musical abilities are autonomous from language abilities, and generally isolable from other cognitive functions, is also given as a prime characteristic of dementia. Demented people are typically described as musically apt while being severely compromised by the disease in their general cognitive functioning (Brontons, 2000). Some demented patients can even learn new songs while being unable to learn how to find their own room in the geriatric care unit (Beatty et al., 1988). G.D.'s general behavior and neurological condition certainly fit this broad characterization. One unexpected outcome of the present investigation was that G.D. stopped his constant mumbling and started humming instead, to the relief of his wife.

General Discussion

The pattern of performance observed in G.D. supports the model by which sung text is governed by the language processing system that mediates normal speech. In G.D., the disruption of speech planning procedures impaired both singing and speaking in a similar manner. Moreover, speech disruption left melodic expression intact. Hence, G.D.'s singing performance provides further evidence for the independence between language and music processing. With this new case, the current evidence is quite consistent in arguing for the complete separation of music and language processors, including in songs where text and melody are so tightly combined.

To our knowledge, all sources of evidence, from behavioral studies to functional neuroimaging studies, point to the autonomy of language and music processors despite the fact that the two functions seem to engage similar processing (Patel, 2003). Even the team of researchers (Serafine et al., 1984, 1986) who were the first to challenge this modular view concluded that text and melody are separable in song memory (Crowder, Serafine, & Repp, 1990). In the final experiment of their series, Crowder and collaborators (1990, Expt. 3) presented spoken texts accompanied by hummed melodies. In these "divided" songs, lyrics and melodies were connected (in time) but retained their physical independence. Nevertheless, participants recognized the melody better when it was paired with the matched studied text (true old pair) than when it was paired with another old text (mismatched pair). The presence of superior recognition for the old pairing over the mismatched one cannot be attributed to the retention of some integrated representation of melody and text because the presentation of each was physically separate. Therefore, the superior retention of

the original combination of text and melody is best understood as the result of the memorization of contingent links between separate memory traces.

This conclusion is also consistent with recent research showing the independence of melody and lyrics in divided attention tasks. For instance, listeners are able to monitor operatic songs for the presence of semantic and tonal incongruities, independently. Supportive evidence has been obtained in the on-line electrophysiological recording of brain responses (Besson, Faïta, Peretz, Bonnel, & Requin, 1998) and in the analysis of behavioral responses with measures derived from the signal detection theory (Bonnel, Faïta, Peretz, & Besson, 2001).

However, as suggested in the introduction of this article, isolation of a cognitive process of interest is not trivial, and much of the current functional neuroimaging research is plagued by this problem. The method of cognitive neuropsychology can be more powerful, as illustrated here. The reason why neurological disorders are so informative regarding the functioning of the brain is that the ensuing deficits often expose the inner workings of a complex system more clearly than with any other method (McCloskey, 2001). Most human activities rely on the operation of highly complex systems. The apparent ease and speed with which these abilities are normally carried out often make it difficult to uncover the underlying mechanisms. By breaking down this smooth functioning, brain damage renders the complex system more amenable to investigation.

Studying abnormalities or malfunctions to shed light on normal structure and processes is a well-established research strategy in health sciences. For example, research on AIDS has contributed to knowledge of the functioning of the normal immune system. Similarly, research on singing performance in aphasics contributes to the understanding of normal singing and speaking abilities. Unlike most diseases, however, homogeneity of the cognitive deficits after brain damage cannot be assumed a priori. This is why cognitive neuropsychology researchers have developed a methodological expertise in the study of single cases. This does not mean that single case data are less valuable or more subject to artifacts than group data. The data of a single case, such as G.D.'s, are as valid as any other method used in cognitive psychology to falsify a theory, because all brain-damaged patients with the same amount of musical experience are assumed to share the same architecture of the system before brain damage. Uniformity of functioning across people is assumed to be as true in cognitive neuropsychology as it is in music cognition and in the cognitive sciences in general. Thus, to challenge the present findings supporting the existence of two distinct pathways for singing the tune and the text of songs, one would need to either argue that the uniformity assumption has been violated in G.D. or to show that there was a methodological problem in our study.

To conclude, a wealth of information can be obtained by studying singing performance in ordinary people. Work on aphasics and amusics is exemplary in this regard because neurologically impaired individuals can serve as their own control. Nevertheless, the study of singing abilities should not be limited to special populations. Singing abilities are basic skills and not the privilege of a select few individuals. Unless a given individual is born with a musical deficiency (e.g., Peretz & Hyde, 2003), humans are equipped with the necessary mechanisms to enable singing.[1]

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