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Le rôle de la musique dans la récupération des paroles de chansons

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Le rôle de la musique dans la récupération des paroles de chansons

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RÉSUMÉ

Une chanson est un alliage naturel de paroles et mélodie, ce qui en fait un médium privilégié pour étudier le lien entre le langage et la musique. La perception de la musique, et son indépendance par rapport à la perception du langage, a reçu jusqu'à présent beaucoup plus d'attention que la production de la musique, cette dernière étant généralement limitée aux musiciens expérimentés. Or, tout le monde peut chanter. Dans cette thèse, le chant sera utilisé pour étudier le rôle de la musique dans la récupération de paroles de chanson. La musique constitue-t-elle une aide valable lors du rappel ou de la production de textes? Si oui, quels mécanismes sont en jeu? En particulier, il s'agit de voir, par la production du chant, si les paroles et la mélodie d'une même chanson peuvent être emmagasinées sous un même code ou si elles sont emmagasinées sous des codes séparés en mémoire.

Dans le premier volet, l'effet de la musique lors de la présentation et la production de paroles de chansons inconnues est étudié chez 36 participants universitaires, musiciens ou non-musiciens. Les participants entendent les paroles chantées ou parlées et doivent les rappeler en chantant ou en parlant. Il s'avère que la musique n'aide pas à apprendre des paroles, et qu'elle peut même nuire lorsque les participants doivent produire à la fois les mots et la mélodie. De plus, les participants rappellent plus de mots que de notes. Selon ces résultats, le langage et la musique qui forment les chansons semblent être représentées sous des codes séparés en mémoire. De façon surprenante, le débit ralenti du chant et les caractéristiques structurantes de la musique ne viennent pas améliorer le rappel.

Enfin, l'expertise musicale n'aide pas dans une tâche d'apprentissage auditive puisque les non-musiciens rappelaient autant de la chanson que les musiciens.

Le deuxième volet s'attarde aux patients souffrant d'une aphasie expressive. On a longtemps pensé que les personnes aphasiques pouvaient chanter des mots qu'ils ne pouvaient pas prononcer autrement. Dans notre étude, les patients répètent les paroles de chansons connues et inconnues, en chantant ou en parlant. La quantité et la qualité des mots produits sont équivalentes en chantant et en parlant. La majorité des patients présentent une aphasie sans amusie, ce qui suggère encore une fois que les deux systèmes sont indépendants. Le chant n'augmente donc pas la production du langage chez les patients aphasiques. La production de matériel automatisé chanté (chansons) est toutefois facilitée par rapport à la production de matériel automatisé parlé (proverbes et prières). Enfin, lorsqu'ils produisent à l'unisson, les patients ont bénéficié du chant en prononçant plus de mots intelligibles que lorsqu'ils parlaient, la synchronisation étant plus aisée et le débit de la parole étant alors significativement ralenti.

Les résultats des études menées auprès de participants universitaires et aphasiques suggèrent que mélodies et paroles de chansons sont emmagasinés sous des codes séparés, tout au moins au début de l'exposition à la chanson, et que la musique ne facilite pas l'accès aux paroles. La musique possède toutefois des bénéfices secondaires qui font que son utilisation demeure pertinente en thérapie.

Mots-clé : langage, mémoire, apprentissage vocal, chant, aphasie, musiciens.

ABSTRACT

Songs are a natural combination of lyrics and melody and are thus an ideal way to study the association between music and language. Music perception has received much attention and it is now known to be independent of language perception. Much less is known about music production since it refers to abilities that are usually restricted to professional musicians; however, everybody can sing. In the present thesis, singing will be used to study the role of music in the retrieval of song lyrics. Is music helpful during recall or production of a text? If yes, what explains this facilitation? We are particularly interested in using singing to establish whether the lyrics and melody of a same song can be stored as a single code in memory or whether they are independently represented.

In the first part of the thesis, the effect of music at encoding and at response during learning of unfamiliar songs is studied in 36 university students, musicians and non-musicians. In this study, the participants hear the lyrics sung or spoken and have to recall them by singing or by speaking. It is shown that music does not improve the recall of lyrics and can even interfere with recall when participants have to produce both the lyrics and the melody. Moreover, participants recall more words than musical notes. According to these results, language and music seem to be coded separately in memory for songs. Surprisingly, the reduced speed of singing compared to speaking and the structural constraints of music do not improve song learning. Finally, musical expertise does not help musicians recall more of the songs compared to non-musicians.

The second part of the thesis concerns patients suffering from non-fluent aphasia. There is a classical observation in neurology that aphasic patients can sing words they cannot pronounce otherwise. In our study, aphasic patients repeated and recalled lyrics of familiar and unfamiliar songs, by singing or by speaking. The quantity and the quality of words produced were similar in singing and in speaking. If word production is altered in these patients, note production is preserved, which suggests that language and music are independent. Singing does not improve word production in aphasic patients *per se*. Production of familiar sung material (songs) is, however, more accurate than the production of equally familiar spoken material (prayers and proverbs). Finally, aphasic patients produce more intelligible words when singing in unison than when speaking alone, since sung production constitutes a more natural way to reduce the rate of speech.

According to the results obtained with university students and aphasic patients, song melody and lyrics are stored in separate codes, at least in the first steps of learning, and music does not facilitate word retrieval. However, music has secondary benefits (fluidity, motivation) which justify its use in therapy.

Keywords: song, language, music, memory, vocal learning, singing, aphasia, musical expertise.

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ANOVA: Analyse de variance

AQPA: Association Québécoise des Personnes Aphasiques

AVC: Accident vasculaire cérébral

BDAE: Boston Diagnostic Aphasia Examination

BEAM: Batterie d'Évaluation de l'Amusie de Montréal

CD: Compact Disk

CT Scan: Computed Tomography

DAT: Digital Audio Tape

IQ: Intellectual Quotient

M: Mean

MBEA: Montreal Battery of Evaluation of Amusia

MIT: Melodic Intonation Therapy

MQ: Memory Quotient

MRI: Magnetic Resonance Imagery

MSE: Mean Standard Error

PET: Positron Emission Tomography

RAVLT: Rey Auditory Verbal Learning Test

SE: Sandard Error

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AVANT-PROPOS

Cette thèse, portant sur le rôle de la musique dans la récupération des paroles de chansons, est organisée autour de la rédaction de trois articles scientifiques. En guise d'introduction, un chapitre sur les amusies est d'abord inclus (article 1). Les amusies, ou troubles du traitement musical, apportent des informations sur les différentes composantes nécessaires au fonctionnement sain du système musical. Ce chapitre expose donc un modèle du traitement musical, dont certaines composantes seront reprises dans les études expérimentales. L'instrument servant à l'évaluation des amusies qui y est décrit sera en outre utilisé auprès de la population aphasique étudiée dans les articles 3 et 4. L'amusie sans aphasie est l'objet de ce chapitre, afin de justifier la place entière que mérite la musique en recherche, et se veut un prélude aux articles 3 et 4 de la thèse qui s'intéressent plutôt à la dissociation inverse, l'aphasie sans amusie, dans l'optique cette fois d'utiliser le traitement musical préservé pour remédier au déficit verbal.

Le chapitre d'introduction inclut également une section sur la comparaison entre musique et langage, le volet de recherche dans lequel s'inscrit cette thèse. Le potentiel des études sur les chansons, en particulier par le chant, y sera justifié. Les connaissances sur la production musicale sont insuffisantes par rapport à ce qui est connu sur la perception musicale. Plus particulièrement, l'exploration de la musique et du langage par le chant permettrait de donner des informations supplémentaires sur leur statut au sein du modèle. La musique possède effectivement des composantes qui sont indépendantes du langage mais aussi des composantes qui semblent partagées avec le langage, comme c'est le cas pour la prosodie. Ainsi, le traitement perceptif des hauteurs nécessaires pour la musique semble également régir la perception des différentes intonations du langage. De façon similaire, serait-il possible qu'un lexique commun aux paroles et à la mélodie d'une chanson existe?

Suite à cette introduction, les études expérimentales composant la thèse seront présentées et justifiées. L'article 2 s'intéresse à l'effet de la musique sur l'apprentissage de paroles de chansons chez des participants universitaires, musiciens et non-musiciens (« Learning Lyrics : To Sing or not to Sing? »). Il correspond au premier volet du projet de thèse. La musique est fréquemment utilisée comme support à la mémoire de textes. La musique donne-t-elle accès à des mots emmagasinés en mémoire? Si oui, par quels mécanismes? Cet article retrace les études s'étant intéressées à comparer l'apprentissage de paroles chantées et récitées. Les expériences incluses permettent pour la première fois de mesurer l'effet de la musique à la fois en présentation et en production, en utilisant de vraies chansons. En outre, une condition originale est créée, où la présentation parlée des mots comprend aussi le contexte mélodique qui est présent lors de la présentation chantée.

Après avoir clarifié l'effet de la musique sur la récupération des paroles en mémoire dans une population saine, nous nous sommes intéressés à ce qui arrivait quand le code verbal était altéré, comme c'est le cas pour les patients aphasiques, dans le deuxième volet. Un premier article (article 3 : « Revisiting the Dissociation between Singing and Speaking in Expressive Aphasia ») est une étude approfondie d'un cas d'aphasie croisée, sans amusie. L'effet de la musique sur la récupération des paroles peut alors se mesurer lors de la simple répétition de chansons connues et inconnues, puisque le langage est affecté. Le deuxième article de ce volet (article 4), « Making Non-fluent Aphasics Speak: Sing Along! », représente le travail fait auprès de huit patients souffrant de divers troubles de la parole. Cette étude de cas multiples visait à généraliser les résultats obtenus dans l'article 3. L'article résume d'abord les études portant sur le chant des aphasiques. Par la suite, le chant des personnes aphasiques est analysé dans toutes les conditions où la musique serait susceptible d'aider, autant lors de la production de chansons familières, que de séquences automatiques récitées (prières, proverbes) et de chansons non familières. La dernière expérience cherche même à mesurer l'effet d'une production à l'unisson, chantée ou parlée, de paroles non familières et le rôle d'une production ralentie, par le chant, est discuté.

En guise de conclusion, un chapitre co-écrit avec Sylvie Hébert et Isabelle Peretz a été choisi puisqu'il fait le tour de ce qui a été fait sur le chant, le médium utilisé tout au long de cette thèse, autant au niveau cognitif, localisationniste que thérapeutique, en intégrant essentiellement les résultats obtenus dans les recherches menées dans le cadre de cette thèse.

Des exemples sonores des stimuli utilisés dans les différentes études seront disponibles sur le site du laboratoire d'Isabelle Peretz au www.brams.umontreal.ca/peretz/.

INTRODUCTION

Article 1

Accepté pour paraître dans le livre *Neuropsychologie clinique et neurologie du comportement*

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Les amusies

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S'il est évident qu'une atteinte du langage bouleverse une vie, il est plus surprenant de penser qu'une personne puisse consulter pour un problème d'ordre musical, à moins que la musique ne soit son gagne-pain. Or, la musique partage plusieurs caractéristiques avec le langage : elle est présente dans toutes les cultures, est un mode répandu de communication et possède des patrons auditifs, moteurs et écrits structurés pour la définir. Enfin, la musique est associée à un substrat neuronal (Peretz, 2001). Dans un monde sans musique, on aurait toujours accès au contenu du langage, transmis par la parole, mais on perdrait en sensibilité émotive et sociale. Il peut donc s'avérer embarrassant d'être incapable de reconnaître et de réagir à une mélodie connue de tous. Malgré la portée de leurs conséquences, les troubles des habiletés musicales, que l'on nomme les amusies, n'ont pas reçu le même intérêt que leurs pendants verbaux.

Historiquement, l'existence de l'amusie a été documentée à plusieurs reprises. Bouillaud (1865), Proust (1872), Jellinek (1956) et Botez & Wertheim (1959) sont parmi les premiers à avoir décrit des patients souffrant d'amusie, bien que les connaissances dans ce domaine ne permettaient pas encore d'en faire un examen systématique (voir Marin & Perry, 1999 pour une revue). La diversité des atteintes présageait déjà de la complexité des amusies, dont les différents types rappellent les différentes formes d'aphasie. Par exemple, on a décrit des amusies réceptive et expressive, des alexies, des agraphies et des amnésies musicales mais aussi des apraxies instrumentales et des troubles du rythme. L'amusie est aujourd'hui un terme générique servant à désigner les troubles acquis et congénitaux de la perception, de la mémoire, de l'exécution, de la lecture ou de l'écriture musicales qui ne peuvent être attribués à une perte auditive ou à un trouble moteur ou intellectuel (Marin & Perry, 1999).

Certaines difficultés inhérentes à l'étude de la musique peuvent expliquer la rareté des travaux sur ce sujet, en comparaison au langage. D'abord, alors qu'il est entendu que la plupart des gens savent parler, lire et écrire, il existe une grande variabilité des expériences musicales, que des auteurs ont d'ailleurs tenté de classer (Grison, 1972). Initialement, seuls les musiciens ont été étudiés pour des troubles musicaux alors qu'il est connu aujourd'hui que les non-musiciens possèdent aussi des capacités musicales, sans avoir suivi un apprentissage formel (voir, par exemple, Tillmann et al., 2000). En sachant qu'il est possible de présenter une amusie sans être musicien, la population étudiée pour les troubles musicaux a donc pu être élargie. Par ailleurs, la définition même de « musicien » n'est pas encore acceptée à ce jour : qui est musicien entre celui qui sait gratter la guitare et le compositeur-interprète reconnu? L'expertise semble toutefois être une variable fondamentale dans l'étude de la musique puisqu'il est démontré qu'avec l'expérience musicale, un phénomène de plasticité cérébrale s'observe. Certaines zones cérébrales seraient hypertrophiées pour les rendre plus efficaces dans le traitement musical (Pantev et al., 1998; Schlaug et al., 1995; Schneider et al., 2002). Enfin, la musique n'a pas toujours été considérée comme un système spécialisé qui soit digne d'étude; ce n'est que récemment que l'étude des bases neuronales de la musique s'est imposée comme un domaine riche et fécond à part entière (Peretz & Zatorre, 2003).

Dans le présent chapitre, nous discuterons d'abord de l'indépendance du système musical par rapport au système verbal, deux domaines qui ont souvent été comparés. Nous verrons ensuite les amusies acquises et congénitales. Par après, nous décrirons un modèle récent du traitement musical qui servira à présenter des cas d'amusie acquise, ayant été étudiés de façon expérimentale. En parallèle, nous aborderons la latéralisation possible du « cerveau musical ». Nous traiterons enfin des outils existant permettant de faire l'examen des amusies.

MUSIQUE ET LANGAGE

Est-ce que la musique repose sur un système originellement formé pour traiter le langage ou existe-t-il un système voué à la musique? L'étude de l'amusie s'est longtemps limitée aux patients atteints d'aphasie et le plus souvent, les deux troubles étaient associés (voir Marin & Perry, 1999, pour une revue). Dans les cas où amusie et aphasie sont concomitantes, il est effectivement fréquent que les mêmes troubles soient retrouvés aux niveaux verbal et musical. Par exemple, un patient présentant une alexie au niveau verbal peut également souffrir de difficultés de lecture au niveau musical (Kawamura et al., 2000). Le même réseau cérébral est-il impliqué dans les deux traitements ou des réseaux distincts mais adjacents sont alors touchés ? La lecture musicale peut toutefois être sélectivement atteinte (Cappelletti et al., 2000) ou sélectivement préservée (Assal, 1973 ; Signoret et al., 1987 pour un exemple en braille). La présence d'une « double-dissociation » entre lecture alphabétique et lecture de la notation musicale suggère donc que le système musical repose sur un réseau neuronal indépendant du système verbal, du moins en ce qui concerne la lecture.

D'autres cas ont été décrits (Brust, 2001, pour une revue) rapportant, sur d'autres plans que la lecture, une aphasie sans amusie (Basso & Capitani, 1985) ou une amusie sans aphasie (Griffiths et al., 1997 ; Piccirilli et al., 2000). C'est ce profil qui nous intéresse plus particulièrement dans ce chapitre. Parmi ces patients, on retrouve Chébaline et IR, qui sont classiques dans le sens où ils présentent chacun une atteinte massive d'un des deux systèmes. Malgré un accident vasculaire le laissant aphasique, le compositeur russe Chébaline a pu continuer à composer des pièces musicales de haut niveau (Luria et al., 1965). À l'inverse, IR (Peretz et al., 1997) pouvait s'exprimer par la parole mais ne pouvait reconnaître ou produire des airs musicaux qui lui étaient connus auparavant.

Le système musical peut donc être atteint ou préservé de façon sélective par rapport au système verbal. Dans ce cas, la différence entre les deux domaines semble porter sur la nature et non le degré de difficulté. Effectivement, si langage et musique s'inscrivaient sur un continuum de difficulté, une atteinte cérébrale devrait systématiquement affecter le domaine le plus complexe. Or, ce n'est pas le cas. Toutefois, deux domaines peuvent être indépendants à un certain niveau mais associés à un autre. Il est donc essentiel de comparer langage et musique dans des composantes de traitement similaires afin de déceler quels processus sont dissociés et quels processus peuvent être partagés.

Les chansons représentent un bon terrain de comparaison entre langage et musique puisque paroles et mélodie y sont apprises ensemble. Les chansons pourraient-elles posséder un statut particulier en mémoire, où langage et musique seraient traités sous un code unique? Cette idée a donné naissance à des thérapies de réadaptation des troubles du langage telle que la *Melodic Intonation Therapy*, qui se base sur un support de type mélodique et rythmique à la production de la parole (Sparks et al., 1974).

Les mots d'une chanson reviennent souvent quand on en fredonne la mélodie. Chez des participants normaux, l'accès à la mélodie sans avoir aussi accès aux paroles d'une chanson paraît effectivement difficile, soutenant l'hypothèse d'une intégration entre paroles et mélodie (Serafine et al., 1984 ; Serafine et al., 1986). Chez les patients cérébro-lésés, une intégration des paroles et de la mélodie en mémoire pour les chansons a aussi été avancée. Après avoir présenté des chansons non familières à une population de patients ayant subi une lobectomie temporale unilatérale pour contrer une épilepsie, Samson & Zatorre (1991) ont évalué leur reconnaissance des paroles et des mélodies. Ils ont constaté que la reconnaissance des paroles était plus difficile après lobectomie gauche. Cependant, ils ont aussi observé que la reconnaissance de la mélodie dépendait des paroles avec lesquelles elle était initialement apprise. Ces résultats ont amené les auteurs à proposer que la mélodie est intégrée aux paroles en mémoire et que les paroles pourraient bénéficier d'une représentation isolée supplémentaire. En d'autres termes, il y aurait un code double pour les chansons en mémoire : un code où paroles et musique sont intégrés et un autre code pour les paroles seules.

Steinke et al. (2000) ont décrit un patient, KB, dont la forme des troubles suggère également qu'il existe un code intégré en mémoire pour les chansons. À la suite d'un accident vasculaire cérébral (AVC) droit, KB était incapable de reconnaître la musique instrumentale mais sa capacité à reconnaître les mélodies apprises antérieurement avec des paroles était toutefois préservée. La remarquable préservation des chansons est interprétée, par les auteurs, comme le résultat du maintien des paroles en mémoire qui, par association, faciliteraient la reconnaissance de la musique. Ce résultat est aussi compatible avec la proposition de Samson & Zatorre (1991), suivant laquelle il y aurait une mémoire pour les chansons dans laquelle paroles et musique sont intégrés et une autre mémoire, musicale cette fois, pour les musiques instrumentales. Dans ce cas, l'origine du problème de KB serait d'avoir perdu l'accès à la mémoire musicale mais non l'accès à la mémoire des chansons.

Les résultats récents obtenus sur le chant de patients aphasiques vont plutôt à l'encontre de l'idée d'un code intégrant paroles et mélodies de chansons (Hébert et al., 2003 ; Peretz et al., 2004). Les deux patients produisaient avec difficulté les paroles de chansons, que ce soit en chantant ou en parlant, mais pouvaient très bien fredonner leurs mélodies. La préservation de la musique dans ce cas d'aphasie ne semble donc pas donner accès à un code où la parole serait préservée. Il existerait plutôt deux codes séparés pour les chansons, un pour la mélodie et un pour les paroles. Ce dernier serait sélectivement perturbé dans le cas d'une aphasie d'expression et entraverait aussi bien le chant que la parole.

En résumé, l'étude des chansons représente une voie royale pour comparer musique et langage chez l'auditeur et chanteur ordinaire. Malheureusement, peu d'études ont porté sur la question. À cet égard, il est utile de rappeler que tout individu normalement constitué peut chanter. Le chant n'est pas une habileté exclusive des chanteurs professionnels et son étude devrait être envisagée plus systématiquement qu'elle ne l'a été jusqu'ici.

L'AMUSIE CONGÉNITALE

Dans ce qui précède, nous avons décrit des cas d'amusie dite « acquise » après atteinte cérébrale. Ce type d'amusie est bien connu puisque présent chez des patients qui sont évalués lors de leur passage dans le système de santé.

L'existence d'une amusie dite congénitale, parce qu'elle serait présente dès la naissance, est une terminologie récente (Peretz & Hyde, 2003). Cette forme d'amusie apparaît sans qu'il n'y ait dommage cérébral ou trouble auditif périphérique ou sensoriel et malgré une intelligence et une exposition à la musique normales. Les individus affectés présentent une incapacité à reconnaître ou fredonner des mélodies familières, une absence de sensibilité à la dissonance, pourtant présente chez les jeunes enfants (Trainor & Heinmiller, 1998), et une difficulté à détecter les fausses notes insérées dans une mélodie (Ayotte et al., 2002). Cette dernière déficience avait déjà été relevée dans une étude antérieure menée auprès de la population britannique (Kalmus & Fry, 1980). Environ 4% de la population serait porteuse de ce trouble amusique.

L'origine de ce trouble amusique pourrait émaner d'une difficulté à discriminer les hauteurs des notes lorsque celles-ci sont à un demi-ton de distance (correspondant aux notes adjacentes sur un clavier). Cette difficulté expliquerait que les amusiques ne peuvent percevoir adéquatement, et donc mémoriser, une mélodie qui utilise des intervalles de l'ordre du demi-ton. Certains amusiques sont toutefois à même de distinguer une question d'une affirmation, lesquelles se différencient aussi par un changement de hauteurs (Ayotte et al., 2002). Cependant, dans la parole, l'intonation couvre des distances beaucoup plus larges qu'en musique, ce qui expliquerait que l'analyse de l'intonation serait épargnée par le trouble de discrimination fine des hauteurs dont souffrent les amusiques. Cette déficience, qui serait à la base de l'amusie congénitale, ne serait pas spécifique à la musique. Le trouble serait toutefois particulièrement pertinent au traitement de la musique, qui comprend des différences de hauteurs plus subtiles que le langage (Peretz & Hyde, 2003).

D'autres auteurs ont également cherché l'origine des troubles musicaux acquis à un niveau acoustique (Griffiths et al., 1997). Ce niveau réfère aux composantes perceptives de base telles que la fréquence, la durée, l'intensité et le timbre du son. Cette analyse s'effectuerait essentiellement au niveau de l'aire auditive primaire située dans les gyri de Heschl (Zatorre & Binder, 2000). L'ancrage acoustique de l'analyse musicale doit être exploré plus à fond afin de déterminer si un déficit à ce niveau peut expliquer certaines formes d'amusie acquise. Dans ce cas, le traitement acoustique (atteint) devrait concerner à la fois musique et langage.

UN MODÈLE DU TRAITEMENT MUSICAL

Afin d'expliquer comment tout un chacun reconnaît une mélodie, Peretz introduit en 1993a un modèle dans lequel perception et mémoire musicales sont représentées de façon modulaire. Ce modèle a été construit principalement à partir d'études portant sur la reconnaissance musicale, cette faculté étant donnée à tous, musiciens comme non-musiciens. Nous présentons ici la dernière version de ce modèle (Peretz & Coltheart, 2003), devenu un modèle général du traitement musical. Ce modèle permet de visualiser les différentes composantes du traitement musical dont l'altération peut créer un déficit de type « amusique ». La défaillance d'une composante (une boîte) ou de la communication entre deux composantes (une flèche) peut entraîner un trouble des habiletés musicales. Chez un patient, un examen systématique permet de savoir où, dans le modèle, se situe l'atteinte entraînant le trouble musical. Les pathologies peuvent être très instructives à ce titre puisque, en entravant des mécanismes normalement aisés et intégrés, les défaillances permettent de décomposer un système complexe en révélant ses éléments constitutifs (McCloskey, 2001).

[Insérer Figure 1 environ ici]

Au-delà du traitement acoustique mentionné dans la section précédente, on accède à un niveau proprement musical, constitué de deux voies principales qui vont activer les phrases musicales contenues en mémoire. Il s'agit de la voie mélodique, définie par les variations séquentielles des hauteurs (le *quoi*), et de la voie temporelle, définie par les variations séquentielles des durées (le *quand*). En perception, mais aussi dans le chant et en lecture, mélodie et rythme peuvent être atteints sélectivement, ce qui démontre une certaine indépendance (Peretz, 2001). La voie mélodique est privilégiée dans l'accès au lexique musical : on reconnaît une chanson plus facilement si la mélodie est jouée sans le rythme que si le rythme est entendu sans la mélodie (Hébert & Peretz, 1997). De plus, un patient dont la voie mélodique est affectée ne pourra pas compenser par la voie temporelle pour reconnaître une mélodie (Peretz, 1994).

La Voie Mélodique

La voie mélodique est à son tour formée de trois composantes : le contour, les intervalles et la tonalité. Le contour est décrit comme la trajectoire de la ligne mélodique, ses hauts et ses bas. Ce motif serait l'information de base conservée en mémoire à court terme, lors de la première écoute d'une mélodie (Dowling, 1982). Le contour musical est similaire à l'intonation (prosodie), la mélodie du langage. Des études ont d'ailleurs cherché à vérifier dans quelle mesure le même processus est en jeu dans musique et langage, chez des patients amusiques. Il s'avère que la discrimination de contours musicaux et d'intonations (isolées de l'information verbale) peuvent être atteintes ou préservées ensemble, ce qui constitue un indice d'un mécanisme commun au langage et à la musique (Nicholson et al., 2003 ; Patel et al., 1998). Cependant, comme nous l'avons vu précédemment dans le cas de l'amusie congénitale, le traitement du contour intonatoire peut être épargné en présence d'un trouble amusique. Dans ce cas-ci, la dissociation résulterait d'une atteinte peu sévère de l'analyse acoustique des hauteurs, commune à l'intonation et à la musique.

Un bon nombre d'études, menées auprès de patients ayant subi une excision chirurgicale ou utilisant l'imagerie cérébrale chez des participants normaux, soulèvent le rôle du gyrus temporal supérieur droit dans le traitement séquentiel des hauteurs (Zatorre, 1985 ; Zatorre & Binder, 2000 ; Zatorre et al., 1994). Cette région s'associe aux structures plus frontales dans la rétention à court terme de l'information mélodique (Penhune et al., 1999 ; Zatorre & Samson, 1991). Parce que l'hémisphère droit serait spécialisé dans le traitement de la hauteur, les amusies « mélodiques » devraient être plus fréquentes après une lésion droite. Pourtant, les amusies rapportées sont plus souvent retrouvées chez les patients ayant subi une atteinte bilatérale (voir plus bas IR, GL, MS, CN, PKC et RC dans Ayotte et al., 2000), suite à la rupture de l'artère cérébrale moyenne antérieure. La latéralisation de la musique est donc moins franche que celle du langage, latéralisé dans l'hémisphère gauche (Demonet & Thierry, 2001 pour une revue).

Outre la hauteur absolue et le contour mélodique, l'information critique qui permet de reconnaître une mélodie particulière est le patron de ses intervalles, la deuxième composante de la route mélodique. Les intervalles correspondent à la distance exacte entre deux notes consécutives. Contour et intervalles ont été associés à différents modes de traitement musical, soit respectivement l'approche globale et locale d'une mélodie. Ces deux modes de traitement ont été distingués chez des patients cérébro-lésés. Chez les patients ayant subi une lésion temporale gauche, seul le traitement des intervalles est entravé, alors que le traitement du contour est préservé (Liégeois-Chauvel et al., 1998 ; Peretz, 1990). Chez les cérébro-lésés droits, le traitement du contour est affecté mais celui des intervalles est aussi déficitaire. Ainsi, l'approche globale précèderait l'approche locale. En d'autres mots, il semble que l'analyse du contour serve de point d'ancrage à l'analyse des intervalles.

Dans le même sens, une étude classique de Bever & Chiarello (1974), utilisant une tâche d'écoute dichotique impliquant la reconnaissance de mélodies, a permis de mettre en évidence une supériorité de l'oreille droite (attribuée à l'hémisphère gauche) chez les musiciens et une supériorité de l'oreille gauche (donc de l'hémisphère droit) chez les non-musiciens. Les auteurs relient cette différence des structures cérébrales utilisées à une différence du type d'analyse opéré sur la mélodie en démontrant que les musiciens utilisent une approche locale dans leur analyse de la musique alors que les non-musiciens se contentent d'une approche globale du contour mélodique. Cette distinction entre mode de traitement et expertise musicale n'est cependant pas rigide. Les musiciens peuvent être amenés à utiliser le contour global (Peretz & Babaï, 1992) et les non-musiciens à extraire les intervalles locaux (Peretz & Morais, 1987).

La troisième composante de la voie mélodique joue un rôle-clé. Elle concerne l'encodage tonal des intervalles. Cet encodage repose sur l'assimilation des règles qui régissent l'utilisation des hauteurs dans le système tonal occidental. En limitant les combinaisons possibles entre les notes, ces règles du système tonal facilitent la rétention des pièces musicales. La sensibilité à la tonalité apparaît tôt dans la vie, puisque les bébés démontrent déjà une préférence pour la gamme qui progresse par intervalles inégaux, comme c'est le cas dans la plupart des systèmes tonals (Trehub et al., 1999).

Un cas d'amusie illustrant une difficulté à utiliser ces connaissances tonales, alors qu'une utilisation du contour et des intervalles est maintenue et que la voie temporelle est préservée, est celui de GL (Peretz, 1993b). Le patient avait subi une rupture bilatérale de l'artère cérébrale moyenne antérieure. GL n'était pas meilleur dans la détection d'erreurs insérées dans une mélodie (*Anomalous Pitch Detection*) lorsqu'elles étaient hors tonalité plutôt que dans la tonalité et ne préférait pas les extraits tonals aux atonals, contrairement aux participants normaux. La tâche classique de *probe-tone* est une autre façon de mesurer la sensibilité à la tonalité. Dans cette tâche, le participant doit dire si une finale est appropriée ou non avec le contexte tonal présenté préalablement. Par rapport au contexte, un profil peut être dégagé selon le jugement porté sur chaque finale (Krumhansl, 1990). Le profil de GL à cette épreuve n'était pas le profil attendu puisqu'il ne préférait pas la finale respectant les règles de la tonalité. L'indépendance du traitement de la tonalité à l'intérieur de la route mélodique est confirmée par un cas présentant la dissociation inverse : MS, le cas étudié par Tramo et al. (1991), présentait une préservation sélective de la capacité à utiliser la tonalité malgré une perception déficiente de la hauteur, suite à un AVC bilatéral affectant les aires auditives.

En résumé, une amusie due à une altération de la voie mélodique peut affecter le traitement des hauteurs à différents niveaux (contour, intervalles, tonalité). La perception musicale est alors limitée, ainsi que l'accès aux phrases musicales en mémoire. Le traitement des variations en hauteur est largement associé aux aires auditives secondaires de l'hémisphère droit mais pas exclusivement.

La Voie Temporelle

Pour sa part, la voie temporelle comporte deux niveaux d'organisation : la métrique et le rythme. La métrique réfère à la mesure ou l'alternance périodique des temps forts et des temps faibles. Le rythme est décrit comme l'organisation des durées. Chez les cérébro-lésés, rythme et métrique peuvent être sélectivement atteints. Le gyrus temporal supérieur serait impliqué dans la perception du rythme dans sa partie postérieure et dans la perception de la métrique dans sa partie antérieure (Liégeois-Chauvel et al., 1998). Rythme et métrique seraient donc indépendants anatomiquement et fonctionnellement (Peretz, 1990). Néanmoins, les déficits de la route temporelle sont peu présents dans la littérature. Pour les évaluer en perception, des tâches de discrimination seront décrites dans la section d'évaluation des amusies.

En production, le rythme est apprécié par la reproduction de séquences. L'interprétation de la métrique est plutôt basée sur le battement de la mesure sur des styles de musique différents (disco, folklore, classique, ...). À l'aide de ce type de tâches, somme toute relativement différentes, des dissociations entre rythme et métrique ont été décrites (Polk & Kertesz, 1993). Ainsi, Mavlov (1980) a décrit un musicien professionnel qui éprouvait des difficultés au niveau du rythme, puisqu'il ne pouvait reconnaître ou reproduire des séquences rythmiques. Ce trouble rythmique, suite à une lésion vasculaire gauche, semblait être à la source d'une amusie réceptive et expressive sévère. Fries & Swihart (1990) ont plutôt décrit un désordre de la métrique chez un patient. Ce gaucher, ayant subi un AVC temporal droit, ne pouvait battre la mesure à l'écoute de mélodies alors qu'il pouvait reproduire des séquences rythmiques.

En résumé, les atteintes de la voie temporelle peuvent entraver sélectivement le traitement du rythme ou de la métrique. L'impact de ces atteintes ne serait pas nécessairement spécifique au traitement musical mais pourrait toucher toute modalité faisant intervenir un traitement temporel (Mavlov, 1980). Ce constat rencontre une proposition récente voulant que l'hémisphère gauche soit impliqué de façon générale dans le traitement des changements temporels rapides, exigés notamment dans le traitement de la parole, alors que l'hémisphère droit serait spécialisé dans le traitement spectral requis dans le traitement musical (Zatorre et al., 2002). La localisation serait différente non plus selon le domaine concerné mais selon le type de traitement acoustique requis.

Le Lexique Musical

La voie mélodique et la voie temporelle donnent accès au lexique musical, le système contenant les représentations des mélodies déjà entendues et permettant l'acquisition de nouvelles représentations en mémoire. De façon générale, la reconnaissance d'une phrase musicale serait possible seulement si un appariement adéquat se fait entre les représentations abstraites fournies par les deux voies d'analyse (avec un poids plus important pour la voie mélodique dans notre système musical) et la représentation stockée en mémoire au niveau du lexique musical. L'usage du lexique musical ne se limite toutefois pas à la reconnaissance. Il est effectivement possible que les représentations dans le lexique musical viennent activer les voies perceptives, un chemin inverse de celui de la reconnaissance. C'est le cas lorsqu'on entend une mélodie dans notre tête : des régions semblables à celles impliquées en perception sont alors mobilisées (Zatorre et al., 1996). Le lexique musical joue également un rôle en production, en activant les patrons de programmation qui permettent de fredonner ou jouer une mélodie connue.

Selon le modèle expliqué ci-dessus, un trouble de la reconnaissance musicale peut être dû à un déficit de l'accès au lexique musical ou par un dégradation du lexique comme tel. D'abord, si les voies perceptives (en particulier la voie mélodique) sont déficitaires mais que le lexique musical est intact, ce dernier ne pourra être activé correctement pour procéder à l'appariement et donc, à la reconnaissance, à partir d'une entrée auditive. Ici, on pourrait parler d'une amusie aperceptive. Dans ce cas, le chant à partir du lexique musical demeuré intact devrait être néanmoins possible. À notre connaissance, un tel cas n'a pas encore été décrit.

Par contre, si le lexique musical est endommagé, alors la représentation perceptive ne peut être comparée à une représentation en mémoire et les mélodies familières ne peuvent être reconnues. De plus, le chant ou l'interprétation d'une phrase musicale connue sur un instrument ne peuvent être produits sur demande. Enfin, l'écoute de nouvelles mélodies ne devrait plus créer de trace durable. On pourrait alors parler d'une amusie associative, puisque c'est la représentation mnésique qui est perturbée. Chez les patients victimes de lésions vasculaires de l'artère cérébrale moyenne, une plus grande fréquence d'amusie aperceptive suite aux lésions droites et d'amusie associative suite aux lésions gauches a été avancée (Ayotte et al., 2000). Cependant, la confirmation de l'origine du trouble par l'intermédiaire du chant n'a pas été envisagée.

L'atteinte du lexique musical a pu être mieux étudiée chez CN dont l'amusie initialement aperceptive s'est transformée en amusie associative, lors de la récupération d'une atteinte bilatérale du cortex temporal supérieur (Peretz, 1996). Dans les tâches d'apprentissage, CN montrait une performance normale lorsque le matériel consistait en sons de l'environnement et titres de chansons connues mais échouait pour les mélodies de chansons non familières ainsi que familières. Sa discrimination musicale, évaluée au moyen de la Batterie d'Évaluation des Amusies de Montréal (BEAM : Peretz et al., 2003), qui sera décrite dans la prochaine section, était comparable à celle de participants contrôles. C'est donc la mise en mémoire qui faisait défaut et ce, de façon sélective pour l'information musicale. De plus, même lorsque la mémorisation était mesurée de façon implicite, CN ne montrait pas de préférence pour une mélodie déjà présentée par rapport à une mélodie nouvelle. Cette préférence entraînée par le sentiment de familiarité à l'écoute d'une mélodie déjà entendue est nommée le *mere exposure effect* (par exemple, Heingarter & Hall, 1974). CN ne gardait pas trace des mélodies : l'apprentissage de nouveau matériel musical n'était donc plus possible. Pour évaluer le lexique musical, l'identification ou la reconnaissance de chansons connues sont également utilisées. CN pouvait reconnaître les titres ou les paroles de chansons connues mais pas leur mélodie, ce répertoire particulier n'étant plus disponible.

En résumé, le lexique musical est la composante mnésique du modèle. Son altération entrave la reconnaissance et la production (de mémoire) des pièces musicales connues.

Les Émotions

L'expérience de la musique ne se limite pas à la reconnaissance ou au chant d'un air connu. Nous écoutons des pièces musicales d'abord pour les émotions qu'elles nous font vivre. Ces émotions reposeraient sur des composantes musicales qui ne sont pas nécessaires à la reconnaissance, telles que le tempo (lent ou rapide) et le mode (majeur ou mineur) dans lesquels le morceau est joué (Peretz et al., 1998). Le cas d'IR (Peretz et al., 1997), mentionné plus tôt, présente une atteinte vaste et sévère du traitement musical, incluant une impossibilité à reconnaître, à discriminer ou à chanter une mélodie. Elle arrive toutefois à utiliser les déterminants de la musique lui permettant de reconnaître l'émotion, gaie ou triste, d'un extrait musical. Sans avoir accès à la représentation de la pièce en mémoire, elle peut néanmoins en reconnaître l'émotion, ce qui va dans le sens d'une indépendance entre le lexique musical et le module affectif du modèle. En production, les émotions sont au coeur de l'interprétation d'une pièce pour en faire plus qu'une performance mécanique. La composante affective du modèle joue donc un rôle essentiel dans l'expérience musicale. Son étude est néanmoins récente et demeure à explorer davantage.

Les Mémoires Associatives

Outre les émotions, tout un contexte peut être évoqué à l'écoute de la musique : le moment où on a entendu l'extrait pour la première fois, les paroles sur lesquelles la mélodie est chantée, etc. Les mémoires associatives contiennent ces connaissances associées. Pour l'expert, tout un réseau d'informations comprenant les connaissances sur le compositeur, l'époque, le genre musical, etc. s'ajoute pour saisir l'œuvre musicale en profondeur.

Les Musiciens

Jusqu'ici, nous avons vu une variété de troubles amusiques qui peuvent se produire aussi bien chez le musicien que chez le non-musicien. Qu'en est-il des habiletés propres aux musiciens aguerris telles que la lecture ou l'écriture de la musique ? La lecture musicale a jusqu'à maintenant été surtout étudiée chez les participants neurologiquement intacts (Sergent et al., 1992 ; Stewart et al., 2003). Néanmoins, des cas d'alexie musicale ont été rapportés depuis plus d'un siècle (Brust, 1980, pour une revue). Encore récemment, Cappelletti et al. (2000) ont démontré un déficit sélectif de la notation musicale chez une musicienne professionnelle, PKC, qui pouvait par ailleurs lire et écrire les mots correctement. Les autres fonctions musicales telles que la mémoire ou la capacité de jouer de son instrument étaient préservées. L'alexie musicale est dite pure. Stewart & Walsh (2001) lient la déficience de cette patiente à sa lésion du cortex occipito-temporal droit, une des régions activées lors de la lecture chez le musicien n'ayant pas subi de dommage cérébral (Sergent et al., 1992). Pour rendre compte de cette voie musicale éduquée, nous avons ajouté une entrée visuelle et un système de conversion de l'écriture en code musical dans le modèle simplifié de Peretz & Coltheart (2003) ; (voir Figure 2).

[Insérer Figure 2 environ ici]

L'écriture musicale, en dictée ou en copie, est souvent atteinte conjointement avec la lecture musicale (Cappelletti et al., 2000 ; Kawamura et al., 2000). Ces deux habiletés reposent sur l'utilisation de connaissances et procédures spécifiques au code musical écrit, ici représenté par une composante distincte. Lorsque l'atteinte cérébrale affecte cette composante, le trouble affecte tant la lecture que l'écriture musicale.

Outre la lecture et l'écriture, d'autres habiletés ne peuvent être étudiées que chez le musicien, telles qu'interpréter une pièce sur son instrument (Palmer, 1997 pour une revue), composer une œuvre ou improviser. La faible fréquence de musiciens professionnels étudiés a restreint les connaissances permettant de mettre au point un modèle fonctionnel de telles capacités.

L'ÉVALUATION DES AMUSIES

À partir du modèle décrit précédemment et dans l'optique de pouvoir déceler les troubles d'ordre musical, la Batterie d'Évaluation de l'Amusie de Montréal (BEAM) a été conçue (Peretz et al., 2003). Wertheim & Botez (1959) avaient été les premiers à publier une batterie systématisée dédiée à l'évaluation neuropsychologique de patients ayant des habiletés musicales. Par la suite, les batteries de Seashore et al. (1960) et du *Gordon's Musical Aptitude Profile* (1965) ont vu le jour et ont été plus communément utilisées. Comparée à ces batteries, la BEAM a l'avantage d'être plus ciblée puisque son matériel est manipulé systématiquement de façon à étudier isolément les composantes d'un modèle récent de la reconnaissance musical et elle ne se limite pas à évaluer le talent.

La batterie comprend six tests correspondant aux composantes du modèle de Peretz (1993a), soit le contour, les intervalles, la tonalité, le rythme, la métrique et la mémoire musicale. Les mêmes 30 mélodies, composées à partir des règles du système tonal occidental, sont utilisées à travers les différents tests. Pour le versant mélodique et pour l'évaluation du rythme, les tests consistent à juger si deux mélodies entendues sont pareilles ou différentes. Lorsque la mélodie de comparaison est différente, elle se distingue de la première par une seule note. La manipulation consiste à insérer soit une note en dehors de la tonalité qui préserve le contour mélodique (test de tonalité), soit une note qui change la direction du contour sans changer la tonalité (test de contour), soit une note qui modifie l'intervalle tout en préservant le contour (test d'intervalles) ou, enfin, à modifier la durée de deux notes consécutives afin de créer un changement de rythme et non de la métrique. Pour le test de métrique, les participants entendent une seule mélodie plutôt qu'une paire et doivent décider s'il s'agit d'une marche (mesure binaire) ou d'une valse (mesure ternaire). La mélodie comporte alors un accompagnement d'accords pour accentuer la structure temporelle et les participants sont invités à battre la mesure pour les aider à prendre leur décision. Finalement, un test de mémoire incidente est présenté. La tâche consiste à décider si oui ou non chaque mélodie a été présentée au cours des épreuves précédentes.

[Insérer Figure 3 environ ici]

La batterie s'est révélée efficace dans le diagnostic de troubles musicaux chez des patients cérébro-lésés (Ayotte et al., 2000 ; Liégeois-Chauvel et al., 1998 ; Peretz et al., 1997 ; Peretz, 1994 ; Steinke et al., 2001) de même que chez les amusiques congénitaux (Ayotte et al., 2002 ; Peretz et al., 2002). Un score composite basé sur les six tests, s'est avéré sensible et normalement distribué. Un score composite se situant à plus de deux écarts-types de la moyenne correspond à un profil d'amusie (Peretz et al., 2003). Pour en savoir plus sur la batterie, il est possible de se référer au site internet de notre laboratoire (www.fas.umontreal.ca/psy/iperetz.html), où les normes sont également disponibles.

La BEAM est trop simple pour le musicien expérimenté. Elle ne pourra pas, chez eux, mettre en lumière les subtilités d'un déficit musical en cas d'amusie. Il n'existe malheureusement pas de batteries dédiées à l'évaluation musicale des musiciens soupçonnés de souffrir d'amusie. Il faut donc créer des tests sur mesure. Par exemple, quelques musiciens possèdent l'oreille absolue, une habileté particulière à nommer une note entendue ou à chanter une note sans référence. Pour ceux-ci, le processus d'évaluation doit alors être ciblé. La performance (chanter, jouer de son instrument, …), la lecture (lecture à vue à partir d'une partition connue ou inconnue, solfège, identification des signes sur une partition…), l'écriture (copie d'une partition, dictée musicale, …) et les connaissances musicales (identification du style, d'un intervalle, d'un accord majeur ou mineur) doivent être explorées de la même manière, avec des tests ajustés à l'expérience antérieure du musicien.

En conclusion, l'étude systématique et relativement récente des amusies a révélé qu'il existerait un circuit cérébral musical indépendant du système verbal. Cette analyse musicale repose sur un système fort complexe, composé de multiples composantes de traitement pouvant, chacune, être sélectivement atteinte, tant chez le non-musicien que chez le musicien. Mais certaines habiletés demeurent le lot de quelques individus talentueux et peuvent donc rarement être étudiées. Un des champs qui demande d'ailleurs à être exploré plus à fond est celui de la production musicale, du chant à la composition. Il demeure que l'étude des amusies constitue l'une des sources d'information les plus riches dont nous disposons actuellement pour mieux comprendre le cerveau musical.

RÉFÉRENCES

Assal, G. (1973). Aphasie de Wernicke chez un pianiste. *Revue neurologique*, 29, 251-255.

Ayotte, J., Peretz, I. & Hyde, K. (2002). Congenital amusia : A group study of adults afflicted with a music-specific disorder. *Brain*, 125, 238-251.

Ayotte, J., Peretz, I., Rousseau, I., Bard, C. & Bojanowski, M. (2000). Patterns of music agnosia associated with middle cerebral artery infarcts. *Brain*, 123, 1926-1938.

Basso, A. & Capitani, E. (1985). Spared musical abilities in a conductor with global aphasia and ideomotor apraxia. *Journal of Neurology, Neurosurgery and Psychiatry*, 48, 407-412.

Bever, T. & Chiarello, R. (1974). Cerebral dominance in musicians and nonmusicians. *Science*, 185, 537-539.

Botez, M.I. & Wertheim, N. (1959). Expressive aphasia and amusia following right frontal lesion in a right-handed man. *Brain*, 82, 186-202.

Bouillaud, J.B. (1865). Sur la faculté du langage articulé. *Bulletin de l'Académie de Médecine*, 30, 752-768.

Brust, J. (2001). Music and the neurologist: A historical perspective. *Annals of the New York Academy of Sciences*, 930, 143-152.

Brust, J. (1980). Music and language: Musical alexia and agraphia. *Brain*, 103, 367-392.

Cappelletti, M., Waley-Cohen, H., Butterworth, B. & Kopelman, M. (2000). A selective loss of the ability to read and write music. *Neurocase*, 6, 332-341.

Demonet, JF. & Thierry, G. (2001). Language and brain : What is up? What is coming up? *Journal of Clinical and Experimental Neuropsychology*, 23 (1), 49-73.

Dowling, W. (1982). Melodic information processing and its development. Dans D. Deutsch (Ed.), *The psychology of music* (pp. 413-430). New York: Academic Press.

Fries, W. & Swihart, A. (1990). Disturbance of rythm sense following right hemisphere damage. *Neuropsychologia*, 28, 1317-1323.

Gordon, E. (1965). *Musical Aptitude Profile*. Chicago: GIA.

Griffiths, T., Rees, A., Witton, C., Cross, P., Shakir, R. & Green, G. (1997). Spatial and temporal auditory processing deficits following right hemisphere infarction: A psychophysical study. *Brain*, 120, 785-794.

Grison, B. (1972). *Étude sur les altérations musicales au cours des lésions hémisphériques*. Thèse de doctorat, Université de Paris.

Hébert, S. & Peretz, I. (1997). Recognition of music in long-term memory : Are melodic and temporal patterns equal partners? *Memory & Cognition*, 25 (4), 518-533.

Hébert, S., Racette, A., Gagnon, L. & Peretz, I. (2003). Revisiting the dissociation between singing and speaking in expressive aphasia. *Brain*, 126 (8), 1838-1850.

Heingarter, A. & Hall, J. (1974). Affective consequences in adults and children of repeated exposure to auditory stimuli. *Journal of Personality and Social Psychology*, 29, 719-723.

Jellinek, A. (1956). Amusia. *Folia Phoniatr*, 8, 124-149.

Kalmus, H. & Fry, D.B. (1980). On tune deafness (dysmelodia): frequency, development, genetics and musical background. *Annals of Human Genetics*, 43 (4), 369-382.

Kawamura, M., Midorikawa, A. & Kezuka, M. (2000). Cerebral localization of the center for reading and writing music. *NeuroReport*, 11 (14), 3299-3303.

Krumhansl, C.L. (1990*). Cognitive foundations of musical pitch*. New York: Oxford University Press.

Liégeois-Chauvel, C., Peretz, I., Babaï, M., Laguitton, V. & Chauvel, P. (1998). Contribution of different cortical areas in the temporal lobes to music processing. *Brain*, 121, 1853-1867.

Luria, A., Tsvetkova, L. & Futer, J. (1965). Aphasia in a composer. *Journal of Neurological Science*, 2, 288-292.

Marin, O.S. & Perry, D.W. (1999). Neurological aspects of music perception and performance. Dans D. Deutsch (Ed.), *The psychology of music* (pp. 653-724). San Diego: Academic Press.

Mavlov, L. (1980). Amusia due to rythm agnosia in a musician with left hemisphere damage: A non auditory supramodal defect. *Cortex*, 16, 321-338.

McCloskey, M. (2001). The future of cognitive neuropsychology. Dans B. Rapp (Ed.), *The handbook of cognitive neuropsychology: What deficit reveal about the human mind* (pp. 593-610). Philadelphia: Psychology Press.

Nicholson, K.G., Baum, S., Kilgour, A., Koh, C.K., Munhall, K.G. & Cuddy, L.L. (2003). Impaired processing of prosodic and musical patterns after right hemisphere damage. *Brain and Cognition*, 52, 382-389.

Palmer, C. (1997). Music performance. *Annual Review of Psychology*, 48, 115-138.

Pantev, C., Oostenveld, R., Engelien, A., Ross, B., Roberts, L. & Hoke, M. (1998). Increased auditory cortical representation in musicians. *Nature*, 392, 811-814.

Patel, A.D., Peretz, I., Tramo, M. & Labrecque, R. (1998). Processing prosodic and musical patterns : A neuropsychological investigation. *Brain and Language*, 61 (2), 123-144.

Penhune, V.B., Zatorre, R.J. & Feindel, W.H. (1999). The role of auditory cortex in retention of rythmic patterns as studied in patients with temporal lobe removals including Heschl's gyrus. *Neuropsychologia*, 37, 315-331.

Peretz, I. (1990). Processing of local and global musical information in unilateral brain-damaged patients. *Brain*, 113, 1185-1205.

Peretz, I. (1993a). Auditory agnosia: A functional analysis. Dans S. McAdams & E. Bigand (Éds), *Thinking in Sound. The Cognitive Psychology of Human Audition* (pp.199-230). New York: Oxford University Press.

Peretz, I. (1993b). Auditory atonalia for melodies. *Cognitive Neuropsychology*, 10, 21-56.

Peretz, I. (1994). Functional dissociations following bilateral lesions of auditory cortex. *Brain*, 117, 1283-1301.

Peretz, I. (1996). Can we lose memory for music? A case of music agnosia in a nonmusician. *Journal of Cognitive Neuroscience*, 8 (6), 481-496.

Peretz, I. (2001). Musical perception and recognition. Dans B. Rapp (Ed.), *The handbook of cognitive neuropsychology: what deficits reveal about the human mind* (pp. 519-540). Philadelphia: Psychology Press.

Peretz, I., Ayotte, J., Zatorre, R.J., Mehler, J., Ahad, P., Penhune, V.B. & Jutras, B. (2002). Congenital amusia: A disorder of fine-grained pitch discrimination. *Neuron*, 33, 185-191.

Peretz, I. & Babaï, M. (1992). The role of contour and intervals in the recognition of melody parts: Evidence from cerebral asymmetries in musicians. *Neuropsychologia*, 30 (3), 277-292.

Peretz, I., Belleville, S. & Fontaine, S. (1997). Dissociations entre musique et langage après atteinte cérébrale : un nouveau cas d'amusie sans aphasie. *Revue canadienne de psychologie expérimentale*, 51 (4), 354-367.

Peretz, I., Champod, A.-S. & Hyde, K.L. (2003). Varieties of musical disorders : The Montreal Battery of Evaluation of Amusia. *Annals of the New York Academy of Science*, sous presse.

Peretz, I. & Coltheart, M. (2003). Modularity of music processing. *Nature Neuroscience*, 6 (7), 688-691.

Peretz, I., Gagnon, L. & Bouchard, B. (1998). Music and emotion : Perceptual determinants, immediacy and isolation after brain damage. *Cognition*, 68, 111-141.

Peretz, I., Gagnon, L., Hébert, S. & Macoir, J. (2004) Singing in the brain: Insights from cognitive neuropsychology. *Music Perception, 21*, 373-390.

Peretz, I. & Hyde, K.L. (2003). What is specific to music processing? Insights from congenital amusia. *Trends in Cognitive Sciences*, 7 (8), 362-367.

Peretz, I. & Morais, J. (1987). Analytic processing in the classification of melodies as same or different. *Neuropsychologia*, 25 (4), 645-652.

Peretz, I. & Zatorre, R.J. (2003). *The cognitive neuroscience of music.* Oxford: Oxford University Press.

Piccirilli, M., Sciarma, T. & Luzzi, S. (2000). Modularity of music : Evidence from a case of pure amusia. *Journal of Neurology, Neurosurgery and Psychiatry*, 69 (4), 541-545.

Polk, M. & Kertesz, A. (1993). Music and language in degenerative disease of the brain. *Brain and Cognition*, 22, 98-117.

Proust, A. (1872). De l'aphasie. *Archives générales de Médecine*, 1, 147-166, 303-318, 653-685.

Samson, S. & Zatorre, R.J. (1991). Recognition memory for text and melody of songs after unilateral temporal lobe lesion: Evidence for dual encoding. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 17 (4), 793-804.

Schlaug, G., Jäncke, L., Huang, Y., Staiger, J. & Steinmetz, H. (1995). Increased corpus callosum size in musicians, *Neuropsychologia*, 33, 1047-1055.

Schneider, P., Scherg, M., Dosch, G., Specht, H. & Gutschalk, A. (2002). Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nature Neuroscience,* 5 (7), 688-694.

Seashore, C.E. et al. (1960). *Seashore measures of musical talents*. New York: Psychological Corporation.

Serafine, M.L., Crowder, R.G. & Repp, B. (1984). Integration of melody and text in memory for songs. *Cognition*, 16, 285-303.

Serafine, M.L., Davidson, J., Crowder, R.G. & Repp, B.H (1986). On the nature of melody-text integration in memory for songs. *Journal of Memory and Language*, 25, 123-135.

Sergent, J., Zuck, E., Terriah, S. & MacDonald, B. (1992). Distributed neural network underlying musical sight-reading and keyboard performance. *Science*, 257, 106-109.

Signoret, J.L., Van Eeckhout, P., Poncet, M. & Castaigne, P. (1987). Aphasie sans amusie chez un organiste aveugle. *Revue neurologique*, 143, 172-181.

Sparks, R., Helm, N. & Albert, M. (1974). Aphasia rehabilitation resulting from Melodic Intonation Therapy. *Cortex*, 10, 303-316.

Steinke, W.R., Cuddy, L.L. & Jakobson, L.S. (2000). Dissociations among functional subsystems governing melody recognition after right-hemisphere damage. *Cognitive Neuropsychology*, 18 (5), 411-437.

Stewart, L., Henson, R., Kampe, K., Walsh, V., Turner, R., Frith, U. (2003). Brain changes after learning to read and play music. *NeuroImage*, 20 (1), 71-83.

Stewart, L. & Walsh, V. (2001). Neuropsychology: Music of the hemispheres. *Current Biology*, 11, R125-127.

Tillmann, B., Bharucha, J. J., & Bigand, E. (2000). Implicit learning of tonality: a self-organizing approach. *Psychogical Review,* 107 (4), 885-913.

Trainor, L. J., & Heinmiller, B. M. (1998). The development of evaluative responses to music : Infant prefer to listen to consonance over disonance. *Infant Behavior and Development,* 21 (1), 77-88.

Tramo, M., Bharucha, J. & Musiek, F. (1991). Music perception and cognition following bilateral lesions of auditory cortex. *Journal of Cognitive Neuroscience*, 2, 195-212.

Trehub, S., Schellenberg, E. & Kamenetsky, S. (1999). Infants' and adults' perception of scale structure. *Journal of Experimental Psychology: Human Perception & Performance*, 25 (4), 965-975.

Wertheim, N. & Botez, M.I. (1959). Plan d'investigation des fonctions musicales. *Encéphale*, 48, 246-260.

Zatorre, R.J. (1985). Discrimination and recognition of tonal melodies after unilateral cerebral excisions. *Neuropsychologia*, 23 (1), 31-41.

Zatorre, R.J., Belin, P. & Penhune, V.B. (2002). Structure and function of auditory cortex: Music and speech. *Trends in Cognitive Sciences*, 6 (1), 37-46.

Zatorre, R.J. & Binder, J.R. (2000). Functional and structural imaging of the human auditory system. Dans A.W. Toga & J.C. Mazziotta (Eds.), *Brain Mapping: The Systems* (pp. 365-402). San Diego: Academic Press.

Zatorre, R.J., Evans, A. & Meyer, E. (1994). Neural mechanisms underlying melodic perception and memory for pitch. *Journal of Neuroscience*, 14, 1908-1919.

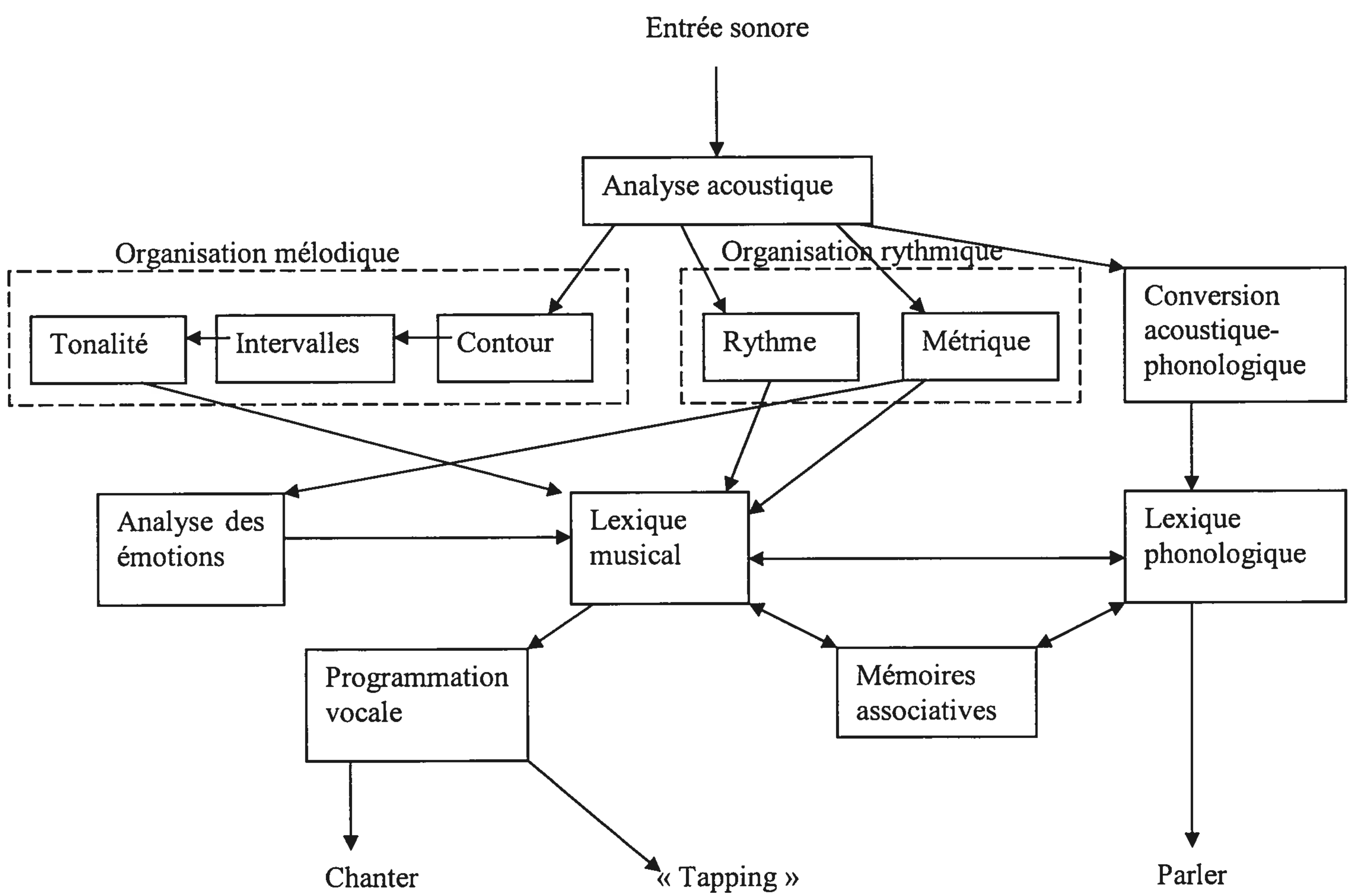
Zatorre, R.J., Halpern, A., Perry, D., Meyer, E. & Evans, A. (1996). Hearing in the mind's ear: A PET investigation of musical imagery and perception. *Journal of Cognitive Neuroscience*, 8, 29-46.

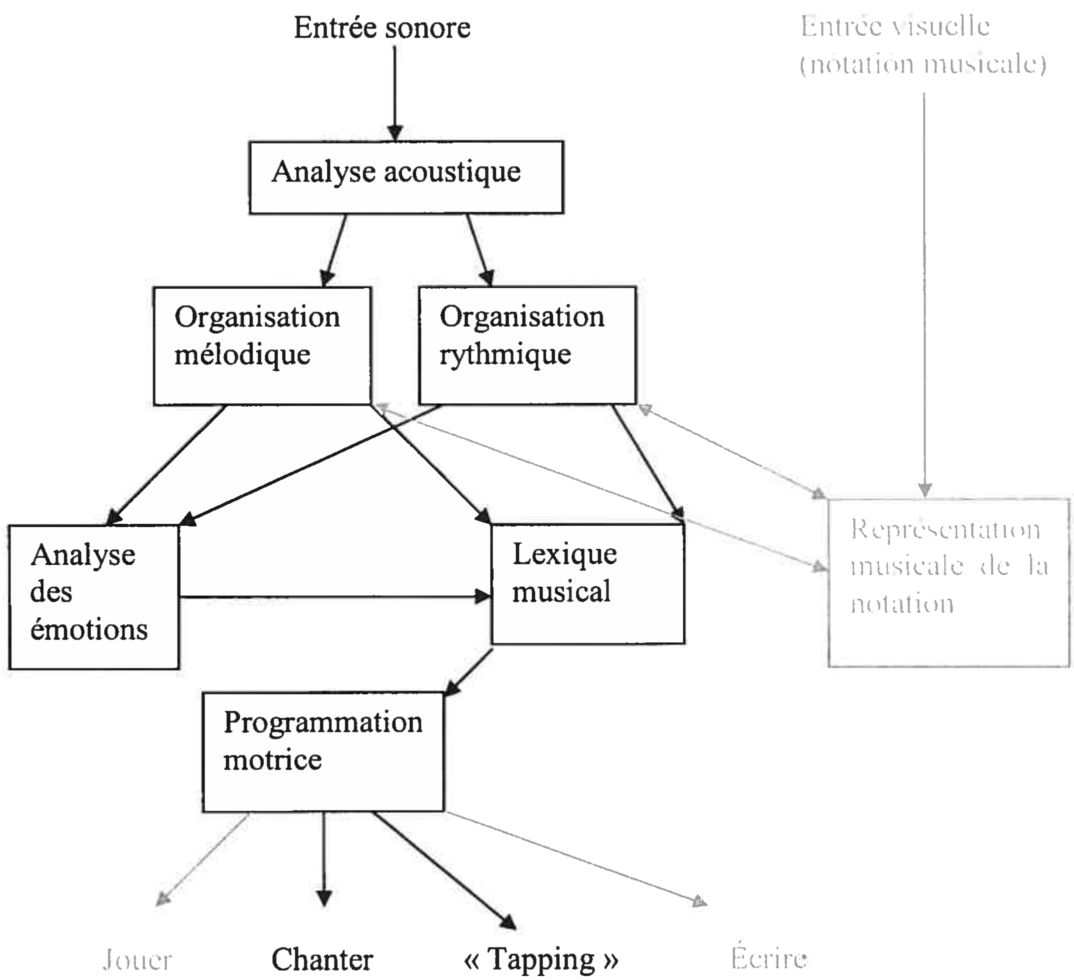
Zatorre, R.J. & Samson, S. (1991). Role of the right temporal neocortex in retention of pitch in auditory short-term memory. *Brain*, 114, 2403-2417.

Figure 1 Le modèle modulaire du traitement musical de Peretz & Coltheart (2003). Une amusie est causée par un dommage à une composante (boîte) ou au flot d'information entre les composantes (flèche).

Figure 2 Un modèle de la lecture et de l'écriture musicales. Les modules en gris sont des ajouts au modèle de Peretz et Coltheart (2003).

Figure 3 Exemple d'un stimulus musical utilisé dans les six sous-tests de la BEAM, en présentation auditive. Le stimulus original est représenté en A, le test de tonalité en B, le test de contour en C, le test d'intervalles en D et le test de rythme en E. L'astérisque identifie la note modifiée. L'accompagnement ajouté pour le test de métrique apparaît en F.


Entrée sonore
Analyse acoustique
Organisation mélodique
Tonalité
Intervalles
Contour
Organisation rythmique
Rythme
Métrique
Conversion acoustique-phonologique
Analyse des émotions
Lexique musical
Lexique phonologique
Programmation vocale
Mémoires associatives
Chanter
« Tapping »
Parler


Entrée sonore
Entrée visuelle
(notation musicale)
Analyse acoustique
Organisation mélodique
Organisation rythmique
Analyse des émotions
Lexique musical
Représentation musicale de la notation
Programmation motrice
Jouer
Chanter
« Tapping »
Écrire

Stimuli

INTRODUCTION À LA PARTIE EXPÉRIMENTALE

Comme on l'a vu dans le chapitre précédent, peu est connu du traitement musical en termes de production (chant, composition, improvisation, performance musicale, etc.), surtout parce que les études portant sur les habiletés musicales expressives sont généralement réservées aux musiciens. Le chant est une exception puisque musiciens comme non-musiciens peuvent chanter. Mais, les études du chant sont peu nombreuses. La présente thèse se présente comme une occasion de défricher, à l'aide de tests comportementaux, le chant de non-musiciens, de musiciens et de patients cérébro-lésés. Plus particulièrement, la musique et le langage ont été comparés à travers le chant, à l'aide de chansons.

Le point de départ de la thèse réside dans l'observation classique en neurologie selon laquelle des aphasiques arrivent à chanter correctement les paroles de chansons qui leur sont connues alors que leur production spontanée du langage parlé est déficiente (Assal, Buttet et Javet, 1977 ; Keith et Aronson, 1975 ; Yamadori, Osumi, Masuhara et Okubo, 1977). Ces études sont cependant anecdotiques, parce que faisant une description peu systématique de la production d'une seule chanson, mais ouvrent la voie à de plus amples explorations du rôle facilitant de la musique sur le langage.

Un bon exemple qui s'inspire de ce rôle dans la récupération du langage chez des aphasiques est la *Melodic Intonation Therapy* (MIT). Dans un rapport de 1994, l'*American Academy of Neurology* considère cette forme de thérapie comme prometteuse pour les aphasiques de Broca. Cette thérapie est aussi utilisée en langue française pour devenir la thérapie d'intonation mélodique et rythmée (Van Eeckhout, Pillon, Signoret, Deloche & Seron, 1984). La MIT met l'emphase sur un patron exagéré et simplifié, progressivement diminué, du rythme, de la prosodie et des accents pour les phrases travaillées avec le thérapeute (Sparks, Albert & Helm, 1974). Ces composantes sont liées à celles retrouvées dans le chant. La MIT semble obtenir des résultats positifs surtout chez les patients présentant les caractéristiques typiques de l'aphasie de Broca, dont un discours sévèrement atteint (Helm-Estabrooks, 1983; Naeser & Helm-Estabrooks, 1985; Sparks et al., 1974).

Les fondements de la MIT ont été peu explorés. Plus qu'évaluer la MIT, l'idée ici est d'en utiliser le principe pour examiner le phénomène de facilitation de la production de la parole par le chant. La question est ensuite de savoir comment le support de type musical, offert entre autres dans la MIT, permet une récupération du langage chez les aphasiques. La première hypothèse est que les éléments verbaux et musicaux composant une chanson pourraient être emmagasinés sous un code intégré en mémoire. Ainsi, la musique pourrait donner accès à ce code qui comprend aussi des paroles et faciliter la production du langage. Au départ, un phénomène de plasticité a effectivement été invoqué pour expliquer les réponses à la MIT: la musique activant plus fortement l'hémisphère droit, celui-ci pourrait prendre en charge le traitement du langage normalement laissé à l'hémisphère cérébral gauche (Cappa & Vallar, 1992). À l'aide de techniques d'imagerie, il a effectivement été observé que ce sont d'abord les régions de l'hémisphère droit qui s'activent plus lors de la réadaptation (Heiss, Kessler, Thiel, Ghaemi et Karbe, 1999 ; Papanicolaou, Moore, Deutsch, Levin et Eisenberg, 1988) mais qu'une récupération optimale ne se fait que par la réactivation de l'hémisphère gauche (Belin et al., 1996 ; Heiss et al., 1999). Des composantes non verbales, voire musicales, qui relèvent de l'hémisphère gauche pourraient être à l'origine de l'effet facilitant dans ce cas.

L'évaluation du chant possède donc un intérêt clinique : vérifier s'il y a de véritables raisons de penser que, par la musique, des aphasiques vont arriver à améliorer leur production altérée du langage. Mais l'utilisation du chant sert aussi un intérêt neuropsychologique en permettant de voir si la production de langage et musique nécessite une récupération intégrée ou indépendante des deux composantes en mémoire.

Le phénomène de facilitation de la production du langage par le chant n'est pas limité aux patients aphasiques. Même chez les gens sans histoire neurologique, les chansons semblent avoir un statut spécial en mémoire (Serafine et al., 1984, 1986). Il nous est d'ailleurs tous arrivé d'utiliser une mélodie pour chercher à améliorer notre rappel d'un texte. Comme nous le verrons dans l'article 2, les études à ce sujet ne sont pas concluantes.

Dans cette thèse, nous chercherons d'abord à savoir si la musique exerce effectivement un effet facilitant sur le langage, puis à voir quels mécanismes sont à l'origine de la facilitation. Le rôle de la musique sera d'abord étudié en mémoire chez les personnes neurologiquement intactes, puis en production chez les aphasiques, afin de voir si la musique se présente comme une voie de contournement quand le langage est touché. Pour ce faire, une procédure d'apprentissage de chansons non familières a été créée et adaptée aux deux populations. Les chansons sont apprises dans quatre conditions (voir Table 8, article 4) : les participants peuvent entendre la chanson chantée et la produire en chantant, l'entendre chantée et la produire en parlant, l'entendre parlée et la produire en parlant ou l'entendre fredonnée et la produire en fredonnant. Notre hypothèse est qu'une présentation chantée, de même qu'une production chantée, sera supérieure à une présentation parlée, et une production parlée. En effet, au-delà de l'hypothèse du code intégré de paroles et mélodie en mémoire, plusieurs raisons peuvent venir expliquer l'effet facilitant de la musique sur la production du langage. Par exemple, la musique ralentit le débit sur lequel la parole est produite (Pilon, McIntosh & Thaut, 1998). De plus, la mélodie impose une structure qui limite le choix des mots pouvant s'y imbriquer (Rubin, 1995). Advenant le fait que notre hypothèse soit confirmée par les résultats, il s'agit ensuite de déterminer la nature de l'effet facilitant.

RÉFÉRENCES

American Academy of Neurology (1994). Assessment: Melodic intonation therapy. *Neurology, 44*, 566-568.

Assal, G., Buttet, J. & Javet, R.C. (1977). Aptitudes musicales chez les aphasiques. *Revue médicale de la Suisse Romande, 97(1)*, 5-12.

Belin, P., Van Eeckhout, P., Zilbovicius, M., Remy, P., François, C., Guillaume, S., Chain, F., Rancurel, G. & Samson, Y. (1996). Recovery from nonfluent aphasia after Melodic Intonation Therapy: A PET study. *Neurology, 47*, 1504-1511.

Cappa, S.F. & Vallar, G. (1992). The role of the left and right hemispheres in recovery from aphasia. *Aphasiology, 6*, 359-372.

Heiss, W.-D., Kessler, J., Thiel, A., Ghaemi, M. & Karbe, H. (1999). Differential capacity of left and right hemispheric areas for compensation of poststroke aphasia. *Annals of Neurology, 45(4)*, 430-438.

Helm-Estabrooks, N. (1983). Exploiting the right hemisphere for language rehabilitation : Melodic Intonation Therapy. *Cognitive Processing in the Right Hemisphere*, 229-240.

Keith, R.L. & Aronson, A.E. (1975). Singing as therapy for apraxia of speech and aphasia: Report of a case. *Brain and Language, 2(4)*, 483-488.

Naeser, M.A. & Helm-Estabrooks, N. (1985). CT Scan lesion localization and response to Melodic Intonation Therapy with nonfluent aphasia cases. *Cortex, 21*, 203-223.

Papanicolaou, A.C., Moore, B.D., Deutsch, G., Levin, H.S. & Eisenberg, H.M. (1988). Evidence for right-hemisphere involvement in recovery from aphasia. *Archives of Neurology, 45*, 1025-1029.

Pilon, M. A., McIntosh, K. W., & Thaut, M. H. (1998). Auditory vs visual speech timing cues as external rate control to enhance verbal intelligibility in mixed spastic-ataxic dysarthric speakers: A pilot study. *Brain Injury, 12*(9), 793-803.

Rubin, D. C. (1995). *Memory in oral traditions*. New York: Oxford University Press.

Serafine, M.L., Crowder, R.G. & Repp, B. (1984). Integration of melody and text in memory for songs. *Cognition, 16*, 285-303.

Serafine, M.L., Davidson, J., Crowder, R.G. & Repp, B.H (1986). On the nature of melody-text integration in memory for songs. *Journal of Memory and Language, 25*, 123-135.

Sparks, R., Helm, N. & Albert, M. (1974). Aphasia rehabilitation resulting from Melodic Intonation Therapy. *Cortex, 10*, 303-316.

Van Eeckhout, P., Pillon, B., Signoret, J.-L., Deloche, G., Seron, X. (1982). *Rééducation des réductions sévères de l'expression orale : la « thérapie mélodique et rythmée »*. In Seron, X. & Laterre, C. Eds, Rééduquer le cerveau : logopédie, psychologie, neurologie. Bruxelles, Mardaga, 109-121.

Yamadori, A., Osumi, Y., Masuhara, S & Okubo, M. (1977). Preservation of singing in Broca's aphasia. *Journal of Neurology, Neurosurgery and Psychiatry, 40*, 221-224.

PARTIE EXPÉRIMENTALE

Article 2

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Learning Lyrics: To Sing or Not To Sing?

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KEYWORDS: Songs, memory, vocal learning, singing, musical expertise, speech, music

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Abstract

Following common practice and oral tradition, learning lyrics through song should facilitate word recall. In the present study, we provide evidence against this belief. In Experiment 1, 36 university students, half of them musicians, learned an unfamiliar song in three conditions. In the sung-sung condition, the song to be learned was sung and the response was sung too. In the sung-spoken condition, the response was spoken. In the divided-spoken condition, the presented lyrics (accompanied by music) and the response were both spoken. Superior word recall in the sung-sung condition was predicted. However, fewer words were recalled when singing than when speaking. Furthermore, the mode of presentation, whether sung or spoken, had no influence on lyric recall, in both short and long term recall. In Experiment 2, singing was assessed with and without words. Altogether the results indicate that the text and the melody of a song have separate representations in memory, making singing a dual task to perform, at least in the first steps of learning. Interestingly, musical training had little impact on performance, suggesting that vocal learning is a basic and widespread skill.

Learning Lyrics: To Sing or Not To Sing?

The notion that music may serve as a mnemonic technique for learning verbal material has a long history. Minstrels transmitted stories through songs (Calvert & Tart, 1993; Rubin, 1995), and this practice is still influential today. The most familiar experiences are jingles for brand names and the alphabet song children learn. More recent examples consist of learning the laws of physics through karaoke (Dickson & Grant, 2003) or learn English, as a second language, via songs (Medina, 1993). The goal of the present study was to contribute to the understanding of this phenomenon from both an empirical and theoretical perspective.

Indeed, it is not obvious why music should facilitate word recall. There is more to learn in a song than in a text. To our surprise, this simple notion has never been properly assessed. Song learning is typically assessed through written recall (Kilgour, Jakobson & Cuddy, 2000; McElhinney & Annett, 1996; Wallace, 1994). This change in format between perception and performance introduces a bias in word recall in favor of the spoken version; extracting words from the sung version requires filtering out the music component. Moreover, written recall requires participants to perform a task that is not familiar to them. Lyrics are typically learned to be sung, not to be written. Thus, a putative advantage of singing over reciting words should not only occur when encoding the text, but also when producing it. The written mode of responding can only indicate whether the melody of the song helps to encode the words and not whether music helps to learn the words. To properly measure the influence of music on verbal learning requires a vocal response. To our knowledge, this procedure has only been used once (Jellison & Miller, 1982) and the results were negative. Music was found to interfere with digit recall and had no effect on word recall. However, the words were unrelated and probably not optimally aligned to the music, hence introducing an additional difficulty. Thus, to properly test the idea that music may serve as a mnemotechnic for recalling words, one needs not only to examine oral responses but to select material where the words are appropriately set to the music (Gingold & Abravanel, 1987), namely real songs. This was done in the present study.

Although an adequate test of the idea that music facilitates text recall requires consideration of both input and output factors, the influence of music on word recall starts at the encoding stage. Therefore, all prior studies looking at input factors may shed light on the idea that sung words are easier to encode than spoken words. Support for this notion is mixed. In several studies, participants recalled as many sung words as spoken words (Gingold & Abravanel, 1987; Wolfe & Hom, 1993) or they did worse on sung material (Calvert & Billingsley, 1998). Yet, in many other studies, an advantage of sung over spoken presentations has been shown (Calvert & Tart, 1993; Chazin & Neuschatz, 1990; Kilgour et al., 2000; Mc Ehlinney et Annett, 1996; Rainey & Larsen, 2002; Wallace, 1994; Wolfe & Hom, 1993).

This advantage of sung over spoken text at encoding has been attributed to speed (Kilgour et al., 2000) and to melody simplicity (Wallace, 1994). In effect, words are pronounced more slowly when singing than when speaking. When the sung version of a text is compressed to match its spoken duration, there is no longer a difference between recalls, suggesting that the slower rate of singing as compared to speaking is a key variable in song learnability (Kilgour et al., 2000).

Similarly, in order for a text to be recalled better than when presented alone, it has to be presented on a simple and repeated melody, as typically found in songs. Conversely, lyrics that are sung to a complex and changing melody can be more difficult to remember than the spoken version (Wallace, 1994).

Songs also possess structural characteristics that may assist text recall. For instance, the metrical structure of music, or the number of musical notes in a line, can cue word recall. Similarly, song lyrics are usually constrained by both semantics (a story is carried, generally through a schema or a script) and sound patterns (e.g., rhymes, alliteration), that may again limit the possibility of word retrieval. Indeed, when errors occur in song recall, the change usually preserves the rhyme (Rubin, 1995) or the number of syllables in the line (Wallace, 1994).

Nevertheless, as mentioned previously, texts of real songs are not systematically memorized better when sung than when recited (e.g., Gingold & Abravanel, 1987, with children; Wallace, 1994, Experiment 3; Wolfe & Hom, 1993, on post-checks). This lack of consistency might be related to the mode of response, as pointed out previously. Writing down the words or reciting the words requires filtering out the words from the music. This filtering process might be difficult, especially when words are sung at high pitches (Scotto Di Carlo & Germain, 1985). One way to control for this perceptual disparity between sung and spoken presentations is to present the spoken lyrics accompanied by music. We refer to this situation as the "divided song" condition. By adding the musical background, this condition also maintains the presence of the melody at encoding. None of the prior studies that aimed at testing the effect of music on word recall have included such a control condition. Finally, in order to promote the use of musical cues as a structural aid in the retrieval process, one needs to assess sung recall.

Consideration of all these factors is not solely motivated by experimental elegance. The contribution of music to verbal memory is a theoretically important question. As alluded to previously, text and melody are aligned in songs in such a way that they promote binding of speech and musical sounds at multiple levels of processing. These tight relations may enhance memory for relatively distinct representations of text and melody in songs by linking elements of words and tones in a rich, multiple-linked whole (Peretz, Radeau & Arguin, 2004). Alternatively, the text and melody of songs might be integrated in a unitary representation, especially when singing is required. Central to the distinction between these two positions is a difference in the way recall is assumed to operate. If integrated, a part of the song's representation will reinstate the whole, namely singing the melody will reinstate the text. If separate, a part (the melody) may or may not connect with the other part (the text), depending on the strength of the links. Thus, the integrated view of song memory would predict a superior text recall in singing over speaking. In contrast, the separate memory view of song components would predict a singing advantage in the long term, after considerable practice.

The idea that melody and text might be represented in a unitary memory trace has been relatively neglected in performance, but it has been studied in perception and memory. The prevailing paradigm in the field involves the recognition of unrelated song lines (Crowder, Serafine, & Repp, 1990; Morrongiello & Roes, 1990; Peretz, Radeau et al., 2004; Samson & Zatorre, 1991;

Serafine et al., 1984, 1986). In the recognition of song lines, melody and text appear as highly associated, even after a single hearing, hence suggesting that lyrics and melody representations are integrated in memory for songs (Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986). However, there is increasing evidence that the music and language components of songs maintain autonomy in both perception (Besson, Faïta, Peretz, Bonnel & Requin, 1998; Bonnel, Faïta, Peretz & Besson, 2001) and memory (Crowder et al., 1990, Experiment 3; Peretz, 1996). Very recently, we extended these conclusions to singing by studying two brain-damaged patients who suffered from a severe speech disorder without a concomitant musical disorder (Hébert, Racette, Gagnon, & Peretz, 2003; Peretz, Gagnon, Macoir & Hébert, 2004). 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. These neuropsychological findings strongly suggest that singing taps into distinct codes for melody and text. Thus, the present study, conducted with neurologically intact participants, should help us to shed further light on this issue by testing the general population.

The general population is musically untrained. However, we also considered a group of professional musicians because these individuals might exploit musical cues more effectively than nonmusicians and therefore benefit more from the presence of music on text recall. Moreover, musicians seem to have better verbal memory than nonmusicians (Jellison & Miller, 1982; Kilgour et al., 2000; Chan, Ho & Cheung, 1998), apparently since childhood (Ho, Cheung & Chan, 2003). Thus, it is possible that musical training strengthens auditory temporal processing which would mediate verbal recall (Jakobson, Cuddy & Kilgour, 2003; Jellison & Miller, 1982). These results would in turn suggest that music may assist in text recall, but only in those individuals who regularly use the two codes.

Insert Table 1 around here

Therefore, in the present study, 36 students, half with musical expertise, had to learn novel songs in three different conditions. As illustrated in Table 1, the text to be learned was either sung or spoken. When spoken, its corresponding melody was sung on /la/ in the background. Recall of text was either sung (on the melody) or spoken (lyrics alone). We predicted that word recall would be superior in the sung-sung condition, especially for musicians, simply because singing is slowed down compared to normal speech. The sung-spoken condition was expected to be the most difficult because in this condition, the text needs to be extracted from the song. In the divided-spoken condition, there would be no cost of extracting the words, but nor would there be an advantage from hearing them sung (at a slow speed).

EXPERIMENT 1

Method

Participants

Thirty-six French-speaking university students (mean age: 25; range: 20 - 37) who felt comfortable singing were recruited. Half (14 women) of the participants were considered nonmusicians, with a mean of two years of music training before the end of high school. The other half (14 women) were students in the music faculty or professional musicians. They had on average 13.6 years of musical training: five were singers, five had singing as their second instrument and eight had no formal training in singing besides solfeggio. Participants were paid for their participation.

Material

Unfamiliar songs were chosen from the repertoire of a popular French-Canadian folk-singer, author and composer (Claude Gauthier). Six songs with few word or melodic line repetitions were selected. From these, eight-line excerpts were chosen for the learning task (see Appendix for an example). Each line carried, on average, six words and eight notes. Thus, on average, a song contained 49 words (range: 45 - 57) and 68 notes (range: 64 - 74). An additional eight-line excerpt from an unfamiliar choir song by Joseph Steuerlein (1974) served as a training song.

The six song excerpts from Claude Gauthier were considered to be "good" songs, as assessed by seven pilot participants who were unfamiliar with the singer. The judges were presented with the six song excerpts in their original version and these were randomly mixed with excerpts of six hit songs from the same folk-singer. Each excerpt was presented twice in a random order. For each song excerpt, the judges rated its musicality, its simplicity and its potential to be a hit, on three six-point scales where 1 meant poor and 6 excellent. Very similar ratings were obtained for the hits and the experimental songs on each dimension (3.7 and 3.8 for musicality, 3.4 and 3.5 for simplicity and 3.2 and 3.4 for hit potential, with first and second ratings pooled together), supporting the idea that the selected material corresponded to "good" songs.

The six songs and the training song were produced a capella (without instrumental accompaniment) by a female singer, who learned the songs beforehand. The same singer also sung each song on /la/ and pronounced the lyrics with a natural intonation. The best performance of each song in each version was recorded on a DAT Sony via a Shure 565SD microphone, and then transferred into a computer and edited with the Cool Edit program (Syntrillium Software Corporation, 1996). The three versions of the same song served to create two types of stimuli, the sung songs and the "divided" songs. The latter were created by coupling each spoken line with its corresponding melody sung on /la/. In these divided songs, the intensity of the melody had to be decreased by 32%, on average, in order to make the spoken version intelligible. The intelligibility of songs' lyrics in the sung and the divided versions was verified by measuring the number of errors made by the participants when repeating the lines in a spoken mode immediately after hearing them. Mean correct repetitions were 94.8% and 95.3% for sung and divided presentations, respectively, t (35) = .40, SE = 1.46, n.s., suggesting that understanding the words from the sung and divided versions of the songs was equally easy.

As expected, the duration of the spoken version was about 43% shorter than the sung version (with M = 2.51 and 4.40 s per line, respectively; t (47) = 9.60, SE = .20, $p < .01$). Because the divided condition combined both the spoken and the "sung on /la/" versions (M = 4.42 s per line), divided and sung presentations had equivalent durations (M = 4.46 and M = 4.40 s per line, respectively; t (47) = 1.58, SE = .04, n.s.). In the divided condition, the shorter spoken line was placed in the middle of the sung melody, so that it was preceded and followed by equivalent durations of the melody.

Song Analysis

The six songs used in the present study had a theme, most often referring to love. The words used were thus predictable (e.g., amour/love, fleurs/flowers, coeur/heart), but different enough across songs to prevent confusions. Themes diverging from love were related to music (one song) and to patriotism (one song). Frequency of usage of the song words was high. The 155 different words used in the songs had a mean frequency of 2057 per million, including function words, based on a French lexical database (New, Pallier, Ferrand & Matos, 2001): 72% were highly frequent, with a frequency of usage higher than 50 per million. Only 13% of the words had a low frequency, corresponding to less than 15 per million. Rhymes were present in all the six songs except one which only rhymed in the second half (see Appendix). In all songs, there was a one-to-one mapping between syllables and tones, with each syllable coupled to a single note. There were no ties (see Appendix). However, notes outnumbered words, t (47) = 13.49, SE = .17, p < .001, because even if most of the words were monosyllabic (69%), 25% were disyllabic, and 6% were trisyllabic.

Regarding musical structure, the six songs had a stable and standard meter. Four of the six songs had a duple meter (4/4) and the other two, a triple meter (3/4 and 6/8). All the songs were in major mode and written in the key of A flat, C, D, G or F, and two songs contained a single modulation. Even if melodies were chosen for their diversity, the melody parts were highly coherent within a song (see Appendix). Lines respected the grouping preference rules proposed by Lerdahl & Jackendoff (1983), which are mainly based on Gestalt principles, such as symmetry, proximity, similarities and parallelism. Thus, the melodic lines did not contain the same absolute pitches or the exact rhythm, but they were structurally similar.

The alignment between the prosody of the text and the rhythm of the melody conformed to the rules of French songs (Dell, 1989). The last accentuated syllable of the verse coincided with a strong beat. This constraint was present in each of the eight lines of the songs. In addition, the last pronounced syllable of a verse was never sung on more than one note. In French, there is no prescriptive rule regarding the alternation between strongly and weakly stressed syllables. Hence, whether prosodic accents coincide with musical metrical accents, as found in English songs, remains debatable (Palmer & Kelly, 1992).

Procedure

Because pilot observations suggested a high variability in the number of lines participants were able to recall, an adaptive procedure was used. The procedure is represented in Table 2. Participants first heard the whole song excerpt once in order to familiarize themselves with the song. Afterwards, the first line was presented and they had to repeat it. Then, lines were repeated two by two. Once the first four lines were repeated, participants were asked to recall the four lines from the beginning without hearing them again. If more than 80% of the words were recalled, lines 5 and 6 were presented and repeated before participants were again asked to recall every line starting at the beginning. If more than 80% of the words were again recalled, lines 7 and 8 were presented and participants made a last recall of the entire excerpt. Number of words correctly produced was calculated on-line by the experimenter so as to decide if the procedure was to be continued or stopped.

Insert Table 2 around here

Presentation of the song lines was either sung or spoken (with the melody in the background). Repetition was either sung or spoken (see Table 1). In the sung-sung condition, participants listened to the sung version of the lyrics and sung them back. In the sung-spoken condition, participants listened to the sung version of the lines and recalled only the lyrics, by reciting them in a natural way. In the divided-spoken condition, they listened to the divided version of the lines and recalled only the lyrics in a similarly natural manner.

Each participant learned one song in each condition, for a total of three different songs. The order of the conditions was counterbalanced across participants according to a latin square. Care was taken to test each song in each condition across participants in each group. The practice song was learned before each condition in the corresponding version. Participants were asked to do their best to recall the exact words, and if they did not remember a part, to report whatever came to mind. Participants listened to digital recordings through speakers and their performance was recorded on a Sony DAT.

In order to assess verbal memory independently from song memory, the Rey Auditory Verbal Learning Test (RAVLT; Rey, 1964) was administered after the learning of the three songs. In this task, participants had five trials to recall a list of 15 unrelated words. The RAVLT also served as a distraction task. Afterwards, participants were asked to make a written recall[1] of the three songs they had previously learned (excluding the practice song). The time elapsed between recalls was approximately 20 minutes. This delayed recall came as a surprise test because participants were not warned in advance that their memory would be assessed one more time. Since music may help long-term memory (Rainey & Larsen, 2003), 25 of the 36 participants were contacted 7 months later (2 to 10 months after the first administration), and asked again for vocal song recall, which was recorded on tape.

Data Scoring

For text recall, words were considered correct or incorrect, irrespectively of their pitch and duration when sung. Words were chosen over syllables because number of syllables sometimes differed across conditions; mute vowels are often sung but not pronounced. The words had to be produced in the correct order to obtain a point. Omissions and substitutions received no points. A point was lost when words were added and half-points were subtracted when words were mispronounced but recognizable. In cases where participants made an error because they misperceived a word and did not repeat it correctly when first heard, the repeated version of the word was considered correct in recall. Finally, a point was lost if the correct word was spoken instead of sung and vice versa. The total number of words correctly reproduced in the last immediate recall and the delayed recall was then divided by the number of words that could have been produced if recall had been perfect, and multiplied by 100 to obtain a percentage.

The number of lines (4, 6 or 8) attempted in immediate recall was also taken into account. Number of hesitations, defined as a marked pause or a corrected attempt (the participant tried something and then changed her/his answer), was also noted. Finally, the location of breaths was recorded.

In the sung mode of recall, the musical notes in each final recall were transcribed by two independent musicians. The agreement between the judges was very low for rhythm and therefore rhythm was not considered in the present study. Instead, pitch intervals and directions were analyzed. The number of correct notes was defined as the number of notes both judges gave a point to. When there was a disagreement (in 15% of the cases for a total of 228 notes out of 1559 notes produced), the note was discarded. Thus, the musical score corresponded to the number of correct pitches divided by the total number of possible notes minus the notes both raters disagreed upon multiplied by 100.

Results

Performance in the immediate recall of the song was first examined by considering the percentages of words that were correctly sung and spoken after presentation of sung and recited songs. The number of lines completed, the total number of words recalled, the position of the forgotten lines in the song, the type of errors made by the participants, and pitch accuracy were also analyzed. Word recall was also examined as a function of learning condition after a delay of 20 minutes and after several months. Finally, performance in lyric learning was compared to performance in the Rey Auditory Verbal Learning Test.

Immediate Recall

Correct Words

An initial repeated measure analysis of variance (ANOVA) with both group (musician, nonmusician) and order of presentation (1, 2, 3) as the between-subjects variables, and condition (sung-sung, sung-spoken, divided-spoken) as the within-subjects variable was performed on the percentage of words recalled. Since there was no effect of order ($\underline{F}$ (2, 30) = 1.19, $\underline{MSE}$ = 175.84, $\underline{p}$ > .05) and no interaction between order and the other factors, order was not considered in the following analyses.

In Table 3, performance is expressed in percentage of words recalled, as well as in terms of the total number of words recalled and the number of lines attempted. As can be seen, recall appears surprisingly more difficult when participants have to sing, irrespectively of their musical background. This was supported by an ANOVA using condition (sung-sung, sung-spoken, divided-spoken) as the within-subjects variable and group (musician, nonmusician) as the between-subjects variable and performed on percentage of words recalled. The ANOVA revealed a main effect of condition, with $F(2, 68) = 11.78$, $MSE = 165.78$, $p < .001$, and no group effect ($F < 1$) or interaction between condition and group ($F < 1$). Post-hoc Tukey tests revealed that both spoken recalls did not differ ($p > .05$) and were significantly better than sung recall ($p < .01$).

Insert Table 3 around here

Superiority of spoken recall was also apparent when the other measures were considered. When the total number of correct words was considered as the dependent variable, the main effect of condition, $F(2, 68) = 7.34$, $MSE = 78.14$, $p < .01$, also reached significance. There was no group effect ($F < 1$) or interaction with condition ($F < 1$). When considering the number of attempted lines (4, 6 or 8 lines), a similar trend was observed since spoken conditions were superior to the sung condition, $F(2, 68) = 2.83$, $MSE = 2.14$, $p = .07$. Moreover, as shown in Figure 1, nonmusicians could learn as much of the songs as musicians when singing.

Insert Figure 1 around here

Performance on the recall of lyrics was correlated across conditions. Participants tended to produce as many words when singing as when speaking after having encoded them in a sung format, $r\ (36) = .43$, $p < .01$. Similarly, they recited as many words whether these were initially sung or spoken, $r\ (36) = .39$, $p < .02$. Therefore, individual levels of performance remained relatively stable across modes of expression and modes of presentation.

Another aspect that is worth examining is serial recall. The beginning of a song acts as an anchor point for the whole song. This refers to the fact that the beginning of a sequence is determinant for the recall of the sequence in question (Peretz, Radeau et al., 2004). Therefore, recall of the first song lines should be best, and recall should decline as the song progresses. Because the first line was presented twice to participants while the subsequent lines were presented only once, we considered the recall of the second line, which was forgotten by only 17% of the participants and compared it to the recall of the last line. The last line failed to be recalled by 42% of the participants while singing, and by only 18% while reciting. This difference was significant, with $Q\ (2) = 8.78$, $p < .05$, using Cochran's Test. Thus, serial position of the line appears more important in singing than speaking. Moreover, forgetting an entire line was more frequent in sung recall (24% of the lines) than in both spoken recalls (11%; $F\ (2, 70) = 8.25$, $MSE = .02$, $p < .01$). When a line was omitted in singing, the next line was omitted in 71% of the cases. In contrast, when a line was omitted in reciting, 55% of the following lines were missed. This suggests that text recall in singing is more strictly sequential, because it appears to be more dependent on serial order of information than is reciting.

Types of word errors.

Types of errors are useful in determining the nature of the memory code used by participants. For example, a word can be substituted by another in order to preserve the song line structure, and this type of error would be expected to occur more often while singing than speaking. Indeed, words were often replaced by a word with the same number of syllables (e.g., "Je t'écris cette lettre par amitié" FOR "Je t'écris ces mots par amitié"). Similarly, in singing, when a word was omitted, participants could replace it by a meaningless syllable (/na/) in order to preserve line structure. These omissions and substitution errors were assessed with respect to the number of syllables in the line. If a match was found, the line structure was considered preserved. When the number of syllables did not match, the line structure was considered altered. The result of this analysis is presented in Table 4. Other types of errors, such as the addition of words (2% of total errors) or pronunciation errors (0.2%) were too rare to be examined.

As can be seen in Table 4, errors tended to preserve the line structure, especially in singing. An ANOVA with condition (sung-sung, sung-spoken, divided-spoken), type of errors (omission, substitution), and line structure (preserved, altered) as the within-subjects variables, and group (musician, nonmusician) as the between-subjects variable yielded an interaction between type of error and line structure, F (1, 34) = 8.96, MSE = .08, $p < .01$. As expected, the omission of words more often altered the line structure (18% versus 11%; t (35) = 1.90, SE = .04, p = .07), whereas substitutions more often preserved it (23% versus 14%; t (35) = 2.95, SE =.03, $p < .01$). This pattern was not significantly affected by singing, as the interaction with condition was not significant, $F < 1$.

There was no group effect or interaction between group and any other variables. In addition, the substituted words were semantically related to the target (67% of the words), thus keeping the gist of the line (e.g., "si jamais vous trouvez cet homme"/if you ever find this man instead of "si jamais vous tenez cet âme"/if you ever hold this soul). Thus, participants tried to respect both the number of syllables and the meaning of words in their recall of lyrics, regardless of the mode of vocal reproduction.

Insert Table 4 around here

Another factor that is known to enhance memory of lyrics is the presence of rhymes at the end of lines. In order to assess the contribution of rhyme, we examined word errors as a function of their serial position in the line. The final words of each line, that is, those bearing the rhyme, were incorrectly reproduced in only 15 % of the lines (with 19% and 12.5% in singing and reciting, respectively). This error rate was smaller than the one observed for any prior position in the line (i.e., the error rate was 20 % for the initial word of the line, with $t = 2.92$, $SE = .02$, $p < .01$). Moreover, when the last word was replaced by another word, it respected the rhyme in 39% of the cases (e.g. tour for jour).

In order to assess fluency, the number of hesitations per line was examined in each condition (see Table 5). As can be seen, the amount of hesitations was equal for musicians in the singing and speaking conditions, while nonmusicians clearly made fewer hesitations when singing. However, the interaction between condition and group failed to reach significance, $F(2, 68) = 2.88$, $MSE = .03$, $p = .06$.

Finally, participants generally took a breath between lines (75%) instead of during a line. While singing, 47% of them took a breath after each line. While reciting, breaths were often taken after two or three lines. Indeed, more spoken than sung words can be produced in a single breath.

Insert Table 5 around here

Notes

In the sung-sung condition, nonmusicians correctly sang 36% of the notes (SE = 7.8) and 65% of the words (SE = 4.8), while musicians sang 48% of the notes (SE = 7.2) and 56% of the words (SE = 4.3). An ANOVA with material (word, note) as the within-subjects variable and group (musician, nonmusician) as the between-subjects variable revealed an interaction between material and group, $F(1, 34) = 4.61$, $MSE = 413.43$, $p < .05$. While nonmusicians recalled more words than notes, with $p < .01$ using a post hoc Tukey test, musicians did not. Interestingly, musicians did not reproduce more correct pitches than nonmusicians (n.s.). When the total number of correct notes ($M = 13.1$, $SE = 2.83$ for nonmusicians and $M = 19.6$, $SE = 4.17$ for musicians) and words was examined instead of the proportion of correct notes and words (see Table 3), there was no effect of material, $F(1, 34) = 1.85$, $MSE = 97.63$, $p > .05$, and no group effect ($F < 1$), but the interaction was again close to significance, $F(1, 34) = 3.03$, $p = .09$.

Furthermore, there was no significant correlation between note and word recall in nonmusicians, $r(18) = .38$, n.s., or in musicians, $r(18) = .27$, n.s.[2].

Delayed Recall and Long-Term Retention

Recall after a 20-minute delay is presented in Table 6. As can be seen, performance dropped by half. Moreover, word recall appeared to persist longer after a divided-spoken presentation. However, this trend was not significant, as revealed by an ANOVA with condition (sung-sung, sung-spoken, divided-spoken) as the within-subjects variable and group (musician, nonmusician) as the between-subjects variable. The effect of condition failed to reach significance with F (2, 68) = 1.88, MSE = 701.75, n.s. There was no group effect, $F < 1$ or interaction, F (2, 68) = 1.16, n.s..

Insert Table 6 around here

As can be seen in Table 6, very few song lyrics were remembered several months after they had been learned. The practice song, which was repeated three times during the initial procedure, was the most frequently recalled (by 12 of the 25 participants contacted), but it was sung by only three of the 12 participants who recalled it.

Rey Auditory Verbal Learning Test (RAVLT)

In this standard auditory memory test, musicians recalled as many words as nonmusicians (see Figure 2; $F < 1$). Both groups improved across the five trials, with F (4, 136) = 161.28, MSE = 1.17, $p < .001$. Furthermore, no significant correlation was found between performance on the RAVLT and word recall from songs in any of the learning conditions (all r (36) were smaller than .29, $p > .05$).

Insert Figure 2 around here

Discussion

Contrary to expectations, music was found to interfere with rather than facilitate text recall. Participants recalled fewer words when singing than when reciting, despite the fact that words are articulated more slowly when sung.

Moreover, music does not help the recovery of lines after a memory blank. On the contrary, sung recall seems to be more strictly sequential than spoken recall. Recall of a line was more dependent on the recall of the previous line in singing than in reciting. Yet, there were fewer hesitations when singing. Hence, singing can give an impression of fluency, not because lyrics are better retrieved from memory, but because the flow is more continuous. This observation has also been reported in cases of speech disorders (Hébert et al., 2003). This apparent fluency was limited to the musically untrained. Musicians did not hesitate less while singing than when reciting.

The fact that music did not help text recall cannot be ascribed to the fact that people are not used to singing. Musicians, including singers, did not perform differently from nonmusicians. They recalled as many lyrics and as many notes as nonmusicians. Hence, the results suggest that oral recall of lyrics is a widespread ability.

Music not only slightly impaired vocal production, it also had little impact on encoding. There was no difference in word recall between the sung and the divided presentations. Furthermore, there was not the slightest indication that music helped in the long run since the addition of music during song presentation or during participants' response had no effect on long term recalls either.

Yet, all the characteristics that qualify memory in oral tradition governed performance in the present study. Recall of lyrics respected line structure, semantics, rhymes, and front anchoring. This form of memory is commonly used for stories and poems (Rubin, 1995). Contrary to expectations, music does not seem to add much to these constraints. Indeed, the mere quantity of words recalled was positively correlated across conditions, but it was not correlated with note recall. Because the focus of the task was on text recall, it is possible that participants treated music as a secondary task, and hence treated it as an additional demand rather than as an aid for memory. The goal of Experiment 2 was to examine this possibility by asking participants to focus on the musical component.

EXPERIMENT 2

In this second experiment, we compared the recall of text and melody alone and in combination (see Table 7). We reasoned that if there was an advantage of text recall over music because the task demands focused on words in Experiment 1, then asking participants to pay attention to music should improve singing in general, and in musicians in particular. In contrast, if singing is a dual task, producing the melody with the text would require more resources than producing either the text or the melody alone.

Insert Table 7 around here

Method

Participants

Six musicians (three women) and six nonmusicians (five women), for a total of twelve participants (mean age: 23.3; range: 20 - 26), who had participated in Experiment 1, came back for an additional session 11 months later (range: 5 to 13 months). This subgroup was selected on the basis of their availability. No professional singers participated in this second experiment.

Material and Procedure

The sung-sung and divided-spoken versions of the same six songs that were used in Experiment 1 were employed here. However, care was taken to present each participant with the three songs that had not been learned in Experiment 1. Recall was tested with an adaptive procedure, as in Experiment 1, by singing the lyrics, reciting the lyrics or singing on /la/ (Table 7). For the sung melodies on /la/, participants were asked to recall the full eight lines of the song, because accuracy of note production could not be judged on-line by the experimenter. There were no other tasks nor was there a delayed recall.

Data Scoring

The same scoring procedure as that used in Experiment 1 was employed here. For the sung production, raters agreed on 83% of the 562 notes produced. For the sung melodies on /la/, if the number of notes correctly produced in the first recall (lines 1 to 4) was less than 80%, the score was computed over these four lines. If 80% or more notes were recalled, the second recall (lines 1 to 6) was rated. If more than 80% of the notes were recalled, scores were based on the last recall (lines 1 to 8). The musical note score was computed based on the number of correct notes both raters agreed upon, that is, 89% of the 565 notes produced.

Results and Comments

Because of the small number of participants, nonparametric tests were first performed on the data in order to assess whether nonmusicians' performance differed from musicians' performance. There were no differences between the two groups on word recall (sung-sung and divided-spoken conditions) or note recall (sung-sung and divided-hummed conditions; all $p > .05$ by Mann-Whitney Tests). Even singing on /la/ did not significantly differentiate musicians from nonmusicians (see Figure 3; Mann-Whitney Test, $Z = .96$, $p > .05$). These two groups did not differ in performance in Experiment 1 either ($p > .05$). Hence, all twelve participants were considered in a single group and parametric analyses were applied.

Insert Figure 3 around here

As can be seen in Table 8, text recall was again worse when combined with music (sung) than when spoken. However, the trend did not reach significance, $t(11) = 1.34$, $SE = 5.00$, $p > .05$. Participants also tended to learn less words and less lines in singing than in speaking, $t(11) = 1.37$, $SE = 4.91$, n.s., and 2.02, $SE = .37$, $p = .07$, respectively. In order to assess the effect of familiarity with the task, the results obtained by the same participants in Experiment 1 were compared to their results obtained here. Task repetition improved singing, with $t(11) = 2.81$, $SE = 4.69$, $p < .05$, but not reciting, $t(11) = 1.12$, $SE = 6.70$, n.s.. Thus, participants seemed more comfortable with the task than in Experiment 1. However, this improvement was not sufficient to bring word recall to a higher level in singing than in speaking. Again, music does not seem to facilitate word recall.

Insert Table 8 around here

Melody recall was more variable than word recall, both in singing with words and in singing on /la/ (see Table 8). The percentage of notes correctly recalled in singing with and without words did not differ, $t(11) = 1.01$, $SE = 7.76$, n.s. In fact, note recall with words was not better than in Experiment 1, with $M = 50.2$, $SE = 9.0$; $t = 0.63$, n.s. Thus, melody recall generally appears to be poor, whether the focus is on text or music. Participants do not seem to have much flexibility in the quantity of resources they can allocate to the musical component.

The majority of participants (9) did not go further than the fourth line in singing on /la/ (see Figure 3), whereas the majority (7) reached the end of the song when reciting lyrics. Performance in word and note recall was not significantly correlated, whether produced together in singing, $r(12) = .16$, $p > .05$, or produced alone, $r(12) = .30$, $p > .05$.

As in Experiment 1, there were more words than notes correctly recalled in singing. In an ANOVA with material (word, note) and production (combined, alone) as the within-subjects variables and proportions as the dependent variable, a main effect of material was obtained, with more words produced than notes, $F(1, 11) = 6.11$, $MSE = 720.18$ $p < .05$. There was no effect of the mode of production, $F(1, 11) = 3.89$, $MSE = 284.39$, $p > .05$, nor was there an interaction, $F(1, 11) = 2.79$, $MSE = 227.23$, $p > .05$. The same effects were obtained with the total number of words and notes used as the dependent variables.

In summary, the results are similar to those obtained previously, indicating a slight advantage of speaking over singing in text recall. This advantage of text over music does not seem related to a trade-off between the two components. Accuracy in singing the melody was similar whether it carried lyrics or not. Furthermore, there was no correlation between words and notes recalled, suggesting that these two components are supported by separate memory representations.

GENERAL DISCUSSION

The present findings suggest that the best strategy for learning song lyrics is to ignore the melody. The melody seems to interfere rather than facilitate word recall in songs in both musically trained and untrained learners. Music was found to be of little help at both encoding and response for text recall. Hearing the lyrics embedded in the melody (i.e., sung) or spoken with the melody in the background did not affect word recall, even after a time delay (Experiment 1) and task familiarization (Experiment 2). The same conclusion applies to the mode of expression. Having to reproduce both the lyrics and the melody while singing was impaired (Experiment 1) or slightly inferior (Experiment 2) compared to the recall of the text alone. Melody recall was generally less precise than word recall, whether it was sung with the lyrics (Experiment 1 and 2) or on /la/ (Experiment 2), in both musicians and nonmusicians. Thus, the results suggest that, in the first steps of learning a new song, melody and lyrics are remembered separately, making singing a dual task.

The cost of singing was reflected by a 14 % word loss (Experiment 1), but it was associated to an 8 % increase in the recall of notes (Experiment 2); the cost was reliable while the benefit was not. This cost-benefit analysis is more compatible with the view that the melody and lyrics of songs are processed independently (Besson et al., 1998; Bonnel et al., 2001; Peretz, 1996; Hébert & Peretz, 2001) rather than treated as an integrated unit (e.g., Serafine et al., 1984). Thus, the present results extend to singing what has been found in the normal functioning of perception and memory. The present findings are also consistent with recent neuroimaging studies showing that recited and sung lyrics have different neural pathways (Jeffries, Fritz, & Braun, 2003). Relative increases in activity during singing as compared to speaking or listening are observed in bilateral motor structures, with a right hemisphere predominance in the premotor, insular, and auditory regions (Jeffries et al., 2003; Perry et al., 1999). Similarly, transcranial magnetic stimulation in the left inferior frontal region provokes a speech arrest but not a singing arrest (Epstein et al., 1999; Stewart, Walsh, Frith & Rothwell, 2001). Thus, in the vocal mode of expression, the melody and lyrics appear separable both functionally and neuroanatomically.

However, separate production of melody and lyrics does not entail interference, unless attention to one component adversely affects the other. In the present case, it seems that lyric recall was either prioritized or much easier than note recall. Such a discrepancy between the processing of words and notes has repeatedly been found in the literature pertaining to perception of songs, with words always being more salient than musical notes (Hébert & Peretz, 2001; Peretz, Radeau et al., 2004). There are several factors that can account for this advantage of lyrics over melody. First, the lyrics were organized like a poem and hence their memorability benefited from the use of several language constraints that are known to help remembering (Rubin, 1995). Semantics, rhymes and line structure were all found to affect recall, whether recited or sung. In contrast, the melody has no semantics or rhymes, but has rhythm, line structure, and pitch accents. These musical characteristics were instrumental in decreasing hesitations, making singing more fluent, but were not sufficient to give additional assistance to lyric recall. On the contrary, it was observed that when a line was forgotten, participants were usually unable to continue singing, while they continued reciting. This might be a drawback of the strictly sequential nature of singing where melodic lines are represented in connected strings, with front anchoring.

Nevertheless, one important cue for auditory-vocal remembering that is common to both music and poems is rhythm. The regular organization of stresses, mostly alternating between strong and weak beats/syllables, is supposed to limit the words that are compatible with it, and thereby constrain word selection. At least in English, the rhythmic similarity between the prosodic accent structure of spoken words and the metric structure of the melody is striking and has long been noted by linguists (e.g., Hayes & Kaun, 1996; Lerdhal & Jackendoff, 1983). Moreover, Palmer and Kelly (1992) have shown that linguistic accent structure and musical meter are generally aligned in Western songs. Hence, rhythmic structure, as determined by the number of syllables (notes) and the location of primary stress, may serve as a compatible format to set words to tones. By this account, recalling a particular stress pattern in a melody (or spoken text) activates a metrical grid that constrains the type of text (melody) that is compatible with it. A common metrical grid is typically used throughout the same song. Therefore, metric structure provides means by which lines of an entire song are organized in a common hierarchical structure, thereby relating non-adjacent song components and helping memory.

The problem in the present study is that we were unable to assess the specific contribution of rhythm to memory. First, the raters failed to provide consistent judgments for the rhythmic aspect of the productions. Secondly, French is not a stress-based language. Hence, it is possible that musical meter (and rhythm in general) is not as efficient as a memory aid for French lyrics as it is for English lyrics. Yet, as mentioned in the introduction, support for the contribution of music to lyric recall in English is scant (Kilgour et al., 2000, Experiment 1 but not 2; Wallace, 1994, Experiment 1 and 2 but not 3). There are many negative reports, even in English (Calvert & Billingsley, 1998; Jellison & Miller, 1982). Therefore, and even if the contribution of rhythm to lyric recall has not been established yet in French, musical constraints appear of limited help for lyric recall in general.

This conclusion raises the question of why music is believed to be so important for verbal memory, not only in oral tradition but also in everyday-life. We think that it is a myth. Music is not at the service of language. In songs, music contributes to the creation of a general mood that is shared with others (Bowra, 1962; see also Thompson & Russo, in press, for empirical support). As Booth (1981) writes, a singer tells people "nothing they need to decode or learn. He evokes in them ways of seeing life that they already have." (p.28). In fact, oral transmission of text is rarely word-for-word (verbatim) in singing. Although singers believe that they sing the text exactly as heard, they never do so (see Rubin, 1995, for a review). This applies to music recall as well. Singers, with and without musical training, never recall note-for-note what they have been presented (Sloboda & Parker, 1985). Rather, singers memorize a schema in which the surface detail is not retained. Recall involves processes akin to improvisation that fills in structurally important events according to general constraints. Learning a new song for faithful reproduction is thus a laborious task that requires hours of practice.

It is interesting to note that when musicians with different expertise <u>spontaneously</u> learn an opera song, words and melodies are practiced independently before they are practiced together (Ginsborg, 2002). Moreover, expert singers do not take more time than novice singers practicing words and melodies together when learning a new song. Rather, they use more variable modes of learning. This is probably the best procedure to create detailed memory representations in which words and notes are tightly connected. Hence, we may predict that in a follow-up study, a stronger association between words and melodies may emerge with further training of the same songs under variable modes of recall, as observed for highly familiar songs (Peretz, Radeau et al., 2004). Hence, prolonged practice may confer an advantage to singing over reciting, but this would require considerable time and effort, with probably little pay-off for the nonmusician.

Without much practice, however, we found that experts and novices perform quantitatively and qualitatively in a similar manner. This was a rather pleasant unexpected finding because it suggests that everyone is able to sing fairly well, even in the laboratory, and that song learning is a basic, though difficult, skill. That is, singing appears as a musical ability that is shared by musicians and nonmusicians of the same culture. It provides further support to the notion that everyone (unless tone-deaf) is equipped to become musically proficient while only a minority will become experts usually through extensive practice and explicit tutoring (see Bigand, 2003, and Peretz & Hyde, 2003, for recent reviews). Perhaps our expert singers were at a disadvantage here because they did not have the musical score to refer to which, for them, is the normal procedure for learning. In the procedure used here, musicians had to draw on a common auditory-vocal code that has been exercised since childhood for learning popular songs. This widespread mode of vocal learning is a basic mechanism by which humans learn not only to sing but also to speak. This capacity might very well be shaped by innate mechanisms. The capacity to adjust vocal output so as to imitate an auditory model containing arbitrary patterns is a remarkable ability that is rare in the animal kingdom (Merker, 2004). Humans are vocal learners, as are a few bird species, whales and bats, whereas our closest lineages, the chimpanzees are not (Janik & Slater, 1997). This confers to vocal learning a privileged role in the study of the most sophisticated human-specific traits, namely music and speech.

References

Besson, M., Faïta, F., Peretz, I., Bonnel, A.-M., & Requin, J. (1998). Singing in the brain: Independence of Lyrics and Tunes. *Psychological Science, 9* (6), 494-498.

Bigand, E. (2003). More about the musical expertise of musically untrained listeners. *Annals of the New York Academy of Sciences, 999*, 304-312.

Bonnel, A. M., Faita, F., Peretz, I., & Besson, M. (2001). Divided attention between lyrics and tunes of operatic songs: evidence for independent processing. *Perception and Psychophysics, 63*_(7), 1201-1213.

Booth, M. W. (1981). *The experience of songs*. New Haven: Yale University Press.

Bowra, C. (1962). *Primitive song*. London: The Shenval Press.

Calvert, S. L., & Billingsley, R. L. (1998). Young children's recitation and comprehension of information presented by songs. *Journal of Applied Developmental Psychology, 19*, 97-108.

Calvert, S. L., & Tart, M. (1993). Song versus verbal forms for very-long-term, long-term, and short-term verbatim recall. *Journal of Applied Developmental Psychology, 14* (2), 245-260.

Chan, A. S., Ho, Y. C., & Cheung, M. C. (1998). Music training improves verbal memory. *Nature, 396*_(6707), 128.

Chazin, S., & Neuschatz, J. S. (1990). Using a mnemonic to aid in the recall of unfamiliar information. *Perceptual and Motor Skills, 71*, 1067-1071.

Crowder, R. G., Serafine, M. L., & Repp, B. (1990). Physical interaction and association by contiguity in memory for the words and melodies of songs. *Memory & Cognition, 18*(5), 469-476.

Dell, F. (1989). Concordances rythmiques entre la musique et les paroles dans le chant. L'accent de l'e muet dans la chanson française. In M. Dominicy (Ed.), *Le souci des apparences* (pp. 121-136). Bruxelles: Université de Bruxelles.

Dickson, D., & Grant, L. (2003). Physics Karaoke: why not? *Physics Education, 4*, 320-323.

Epstein, C. M., Meador, K. J., Loring, D. W., Wright, R. J., Weissman, J. D., Sheppard, S., Lah, J. J., Puhalovich, F., Gaitan, L. & Davey, K. R. (1999). Localization and characterization of speech arrest during transcranial magnetic stimulation. *Clinical Neurophysiology, 110* (6), 1073-1079.

Gingold, H., & Abravanel, E. (1987). Music as a mnemonic : The effects of good- and bad-music settings on verbatim recall of short passages by young children. *Psychomusicology, 7* (1), 25-39.

Ginsborg, J. (2002). Classical singers learning and memorising a new song: An observational study. *Psychology of Music, 30*, 56-99.

Hayes, N., & Kaun, A. (1996). The role of phonological phrasing in sung and chanted verse. *The Linguistic Review, 13*, 243-303.

Hébert, S., & Peretz, I. (2001). Are text and tune of familiar songs separable by brain damage? *Brain and Cognition, 46* (1-2), 169-175.

Hebert, S., Racette, A., Gagnon, L., & Peretz, I. (2003). Revisiting the dissociation between singing and speaking in expressive aphasia. *Brain, 126* (Pt 8), 1838-1850.

Ho, Y. C., Cheung, M. C., & Chan, A. S. (2003). Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children. *Neuropsychology, 17* (3), 439-450.

Jakobson, L. S., Cuddy, L. L., & Kilgour, A. R. (2003). Time Tagging: A Key to Musicians' Superior Memory. *Music Perception, 20* (3), 307-313.

Janik, V. M., & Slater, P. J. B. (1997). Vocal learning in mammals. *Advances in the Study of Behavior, 26*, 56-99.

Jeffries, K. J., Fritz, J. B., & Braun, A. R. (2003). Words in melody: an $H_2{}^{15}O$ PET study of brain activation during singing and speaking. *NeuroReport, 14* (5), 749-754.

Jellison, J. A., & Miller, N. L. (1982). Recall of digits and word sequences by musicians and nonmusicians as a function of spoken and sung input and task. *Journal of Music Therapy, 19* (4), 194-209.

Kilgour, A. R., Jakobson, L. S., & Cuddy, L. L. (2000). Music training and rate of presentation as mediators of text and song recall. *Memory & Cognition, 28* (5), 700-710.

Lerdahl, F., & Jackendoff, R. (1983). *A generative theory of tonal music.* Cambridge, MA: MIT Press.

McElhinney, M., & Annett, J. M. (1996). Pattern of efficacy of a musical mnemonic on recall of familiar words over several presentations. *Perceptual and Motor Skills, 82* (2), 395-400.

Medina, S. (1993). The effect of music on second language vocabulary acquisition. *National Network for Early Language Learning, 6* (3), 1-8.

Merker, B. (2004). *Vocal learning for song: Key constraint on the path to language*. Unpublished manuscript.

Morrongiello, B. A., & Roes, C. L. (1990). Children's memory for new songs: integration or independent storage of words and tunes? *Journal of Experimental Child Psychology, 50* (1), 25-38.

New, B., Pallier, C., Ferrand, L., & Matos, R. (2001). Une base de données lexicales du français contemporain sur internet: LEXIQUE. *L'Année Psychologique, 101*, 447-462.

Palmer, C., & Kelly, M. H. (1992). Linguistic prosody and musical meter in song. *Journal of Memory and Language, 31*, 525-542.

Peretz, I. (1996). Can we lose memories for music? The case of music agnosia in a nonmusician. *Journal of Cognitive Neurosciences, 8* (6), 481-496.

Peretz, I., Gagnon, L., Hébert, S. & Macoir, J. (2004). Singing in the brain: Insights from cognitive neuropsychology. *Music Perception, 21* (3), 373-390.

Peretz, I., & Hyde, K. (2003). What is specific to music processing ? Insights from congenital amusia. *Trends in Cognitive Sciences, 7* (8), 362-367.

Peretz, I., Radeau, M., & Arguin, M. (2004). Two-way interactions between music and language: evidence from priming recognition of tune and lyrics in familiar songs. *Memory and Cognition, 32* (1), 142-152.

Perry, D. W., Zatorre, R. J., Petrides, M., Alivisatos, B., Meyer, E., & Evans, A. C. (1999). Localization of cerebral activity during simple singing. *NeuroReport, 10* (18), 3979-3984.

Rainey, D., & Larsen, J. (2002). The effect of familiar melodies on initial learning and long-term memory for unconnected text. *Music Perception, 20* (2), 173-186.

Rubin, D. C. (1995). *Memory in oral traditions.* New York: Oxford University Press.

Rey, A. (1964). *L'examen clinique en psychologie.* Paris: Presses universitaires de France.

Samson, S., & Zatorre, R. (1991). Recognition memory for text and melody of songs after unilateral temporal lobe lesion: Evidence for dual encoding. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17* (4), 193-804.

Scotto Di Carlo, N., & Germain, A. (1985). A perceptual study of the influence of pitch on the intelligibility of sung vowels. *Phonetica, 42* (4), 188-197.

Serafine, M. L., Crowder, R. G., & Repp, B. H. (1984). Integration of melody and text in memory for songs. *Cognition, 16* (3), 285-303.

Serafine, M. L., Davidson, R. J., Crowder, R. G., & Repp, B. H. (1986). On the nature of melody. Text integration in memory for songs. *Journal of Memory and Language, 25,* 123-135.

Sloboda, J. A., & Parker, D. H. H. (1985). Immediate recall of melodies. In P. Howell, I. Cross & R. West (Eds.), *Musical structure and cognition* (pp. 143-168). London: Academic Press.

Stewart, L., Walsh, V., Frith, U., & Rothwell, J. (2001). Transcranial magnetic stimulation produces speech arrest but not song arrest. In R. J. Zatorre &

I. Peretz (Eds.), *The biological foundations of music*. New York: The New York Academy of Sciences.

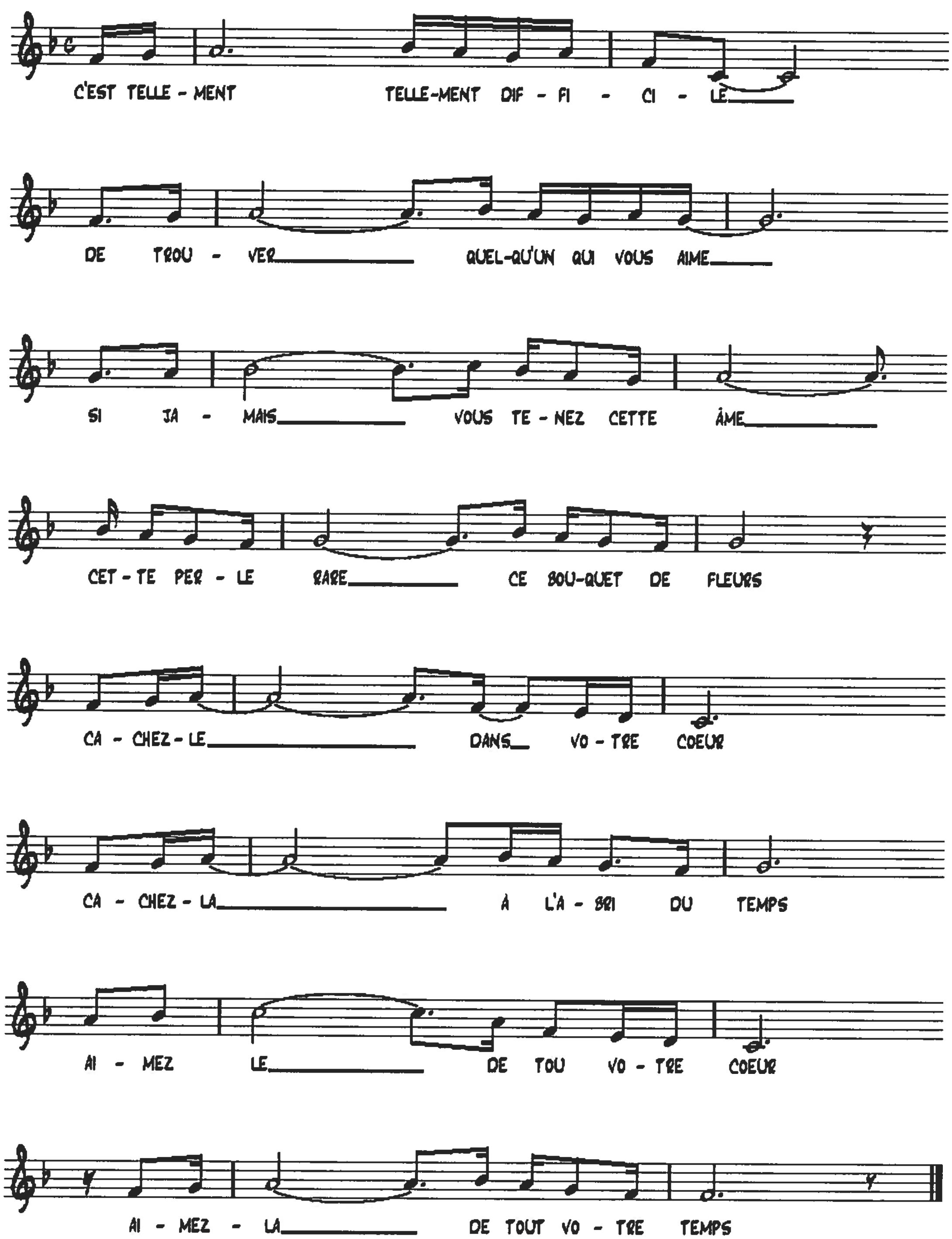
Wallace, W. T. (1994). Memory for music: Effect of melody on recall of text. *Journal of Experimental Psychology : Learning, Memory, and Cognition, 20* (6), 1471-1485.

Wolfe, D. E., & Hom, C. (1993). Use of melodies as structural prompts for learning and retention of sequential verbal information by preschool students. *Journal of Music Therapy, 30* (2), 100-118.

Appendix

CACHEZ-LA

CLAUDE GAUTHIER



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Footnotes

[1] Written delayed recall was used instead of vocal recall in order to avoid confusion between the mode of production and its associated set of lyrics. This also provided an opportunity to assess the effect of music on text encoding as done in most prior studies.

[2] This lack of correlation between verbal and musical recall suggests that these two components are produced independently. To test for independence between word and pitch errors, we need to compute the probability of joint word/pitch errors based on the error rates for the separately occurring word (W) and pitch (P) errors (prob-W multiplied by prob-P; as applied by Drake & Palmer, 2000, to the pitch and time errors obtained in piano performance). However, because 67% of the participants had no errors on the words only and/or on the notes only, the probability of joint errors was mostly zero and hence independence could not be assessed properly.

Table 1.

Modes of Presentation and Recall in the Three Conditions of Experiment 1

Presentation of the Song	Recall of the Lyrics
Sung	Sung
Sung	Spoken
Spoken (divided)	Spoken

Table 2.

Illustration of the Adaptive Learning Procedure

Lyrics presented	Lyrics repeated	Lyrics to be recalled
1 Dans cette petite boîte vide	1 Dans cette petite boîte vide	
1 Dans cette petite boîte vide 2 Avec un ruban de velours	1 Dans cette petite boîte vide 2 Avec un ruban de velours	
3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour	3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour	
		1 Dans cette petite boîte vide 2 Avec un ruban de velours 3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour
		If less than 80% of words recalled, stop If 80% or more words recalled, continue
5 Il n'y a pas d'argent qui remplace 6 Tout le temps que l'on peut donner	5 Il n'y a pas d'argent qui remplace 6 Tout le temps que l'on peut donner	
		1 Dans cette petite boîte vide 2 Avec un ruban de velours 3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour 5 Il n'y a pas d'argent qui remplace 6 Tout le temps que l'on peut donner
		If less than 80% of words recalled, stop If 80% or more words recalled, continue
7 À tous ceux que l'on aime hélas 8 Trop souvent qu'on oublie d'aimer	7 À tous ceux que l'on aime hélas 8 Trop souvent qu'on oublie d'aimer	
		1 Dans cette petite boîte vide 2 Avec un ruban de velours 3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour 5 Il n'y a pas d'argent qui remplace 6 Tout le temps que l'on peut donner 7 À tous ceux que l'on aime hélas 8 Trop souvent qu'on oublie d'aimer

Table 3.

Mean (and Standard Error) Obtained in Each Condition on Immediate Recall in Experiment 1

		Condition		
		Sung-sung	Sung-spoken	Divided-spoken
Group	Dependent Variable			
Nonmusicians	%	63.9 (4.8)	73.0 (3.5)	74.0 (3.2)
	Words	20.4 (2.9)	22.7 (2.3)	27.9 (2.5)
	Lines	5.0 (0.4)	5.0 (0.4)	6.0 (0.4)
Musicians	%	56.1 (4.3)	68.9 (3.0)	73.9 (3.6)
	Words	18.7 (2.3)	23.7 (2.3)	27.1 (3.0)
	Lines	5.2 (0.4)	5.6 (0.4)	5.8 (0.4)
Mean	%	60.0 (3.2)	70.9 (2.3)	74.0 (2.4)
	Words	19.6 (1.8)	23.2 (1.6)	27.5 (1.9)
	Lines	5.1 (0.4)	5.3 (0.4)	5.9 (0.4)

Table 4.

Mean Percentage of Errors (and Standard Error) in Each Condition as a Function of Line Structure

		Condition		
		Sung-sung	Sung-spoken	Divided-spoken
Type	Line structure			
Omissions	Preserved	13 (4)	11 (5)	9 (4)
	Altered	10 (3)	21 (4)	24 (5)
Substitutions	Preserved	20 (4)	27 (4)	22 (4)
	Altered	10 (3)	12 (3)	20 (4)

Table 5.

Mean Percentage of Hesitations per Line (and Standard Error) in Each Condition for Each Group

	Condition		
Group	Sung-sung spoken	Sung-spoken	Divided-
Nonmusicians	6 (3)	26 (5)	21 (4)
Musicians	14 (3)	17 (3)	15 (5)
Mean	9 (3)	21 (4)	18 (5)

Table 6.

Mean Percentage of Correctly Recalled Words (and Standard Error) in the Three Conditions After a 20-Minute Delay and after Several Months (in italics)

	Condition		
Group	Sung-sung	Sung-spoken	Divided-spoken
Nonmusicians	36.7 (6.0)	26.0 (7.2)	38.1 (5.5)
	2	*12*	*13*
Musicians	25.8 (6.7)	32.3 (6.6)	42.9 (7.9)
	14	*5*	*32*
Mean	31.2 (4.5)	29.1 (4.9)	40.5 (4.7)

Table 7.

Modes of Presentation and Recall in the Three Conditions of Experiment 2

Presentation of the Song	Recall of the Lyrics
Sung	Sung
Spoken-Sung on /la/	Spoken
Spoken-Sung on /la/	Sung on /la/

Table 8.

Means (and Standard Error) Obtained for Words and Notes in Experiment 2

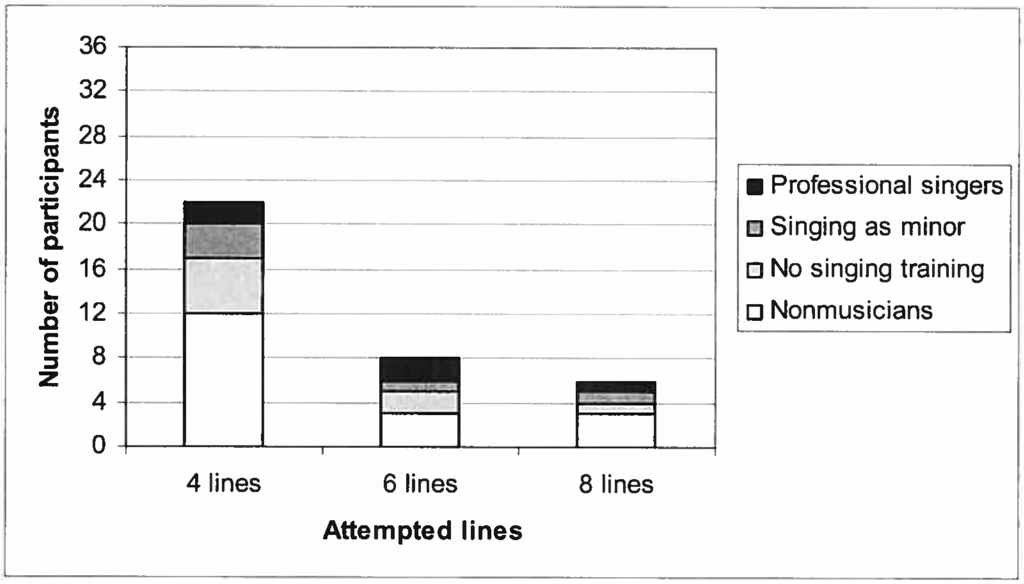
		Production	
Material	Dependent Variable	Combined	Alone
Words	%	70.6 (3.2)	77.3 (3.6)
	Number	25.8 (2.8)	32.5 (2.8)
	Lines	5.5 (0.5)	7.0 (0.4)
Notes	%	58.8 (9.5)	50.9 (6.4)
	Number	23.0 (4.1)	20.8 (4.3)
	Lines	5.5 (0.5)	5.0 (0.5)

Figure Captions

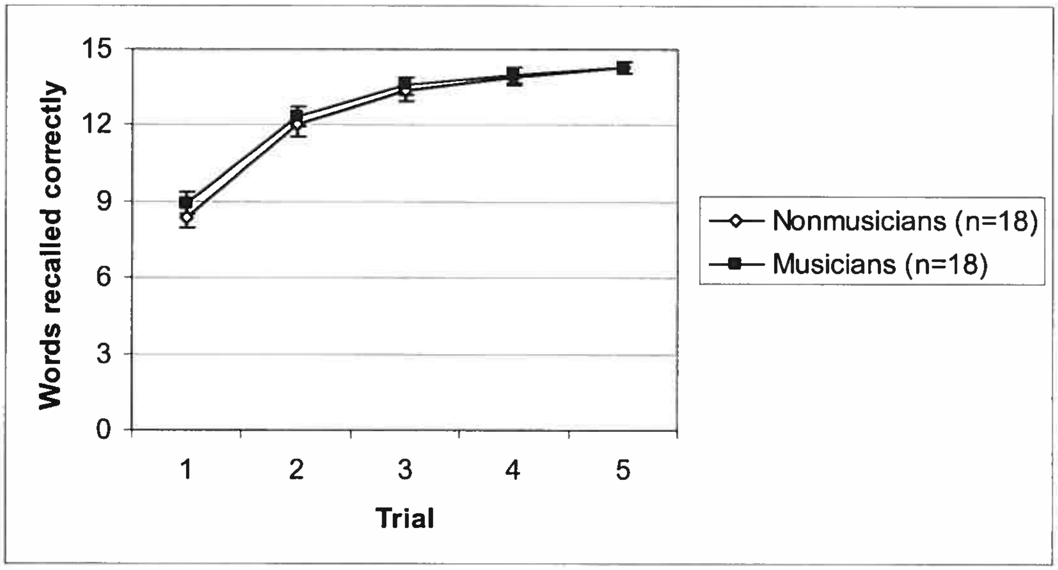
Figure 1. Number of nonmusicians and musicians reaching each level of song line recall, depending on their singing experience in Experiment 1. Nonmusicians are represented in white and musicians in grey shades.

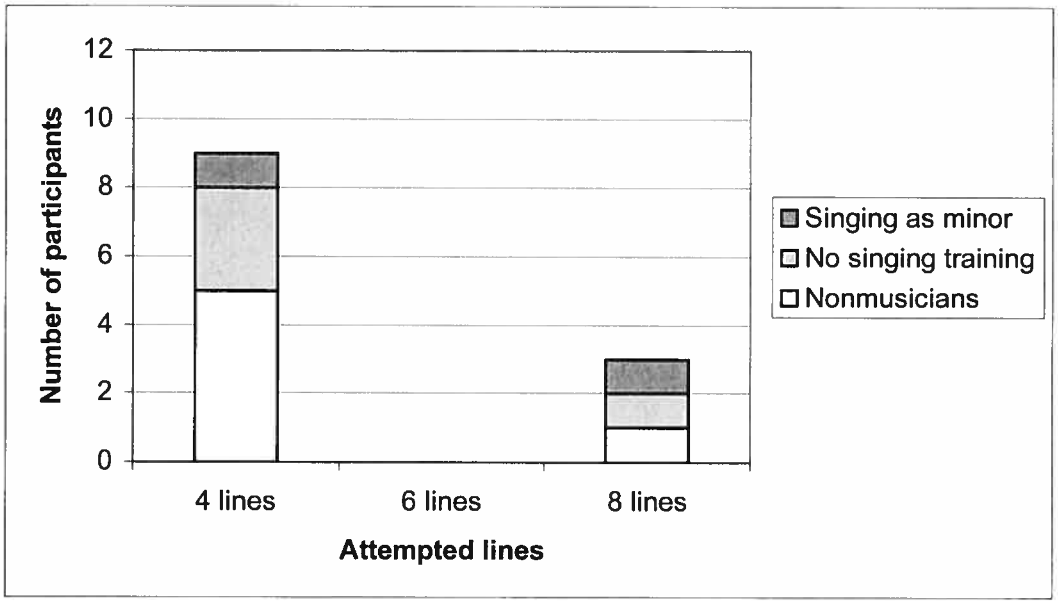
Figure 2. Mean number of recalled words (and standard error) on each trial of the Rey Auditory Verbal Learning Test by nonmusicians and musicians.

Figure 3. Number of nonmusicians and musicians reaching each level of melody line recall, depending on their singing experience, in Experiment 2.



36
32
28
24
20
16
12
8
4
0
Number of participants
4 lines
6 lines
8 lines
Attempted lines
Professional singers
Singing as minor
No singing training
Nonmusicians


15
12
9
6
3
0
Words recalled correctly
1
2
3
4
5
Trial
Nonmusicians (n=18)
Musicians (n=18)



12
10
8
6
4
2
0
Number of participants
4 lines
6 lines
8 lines
Attempted lines
Singing as minor
No singing training
Nonmusicians

Article 3

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Revisiting the dissociation between singing and speaking in expressive aphasia

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Abstract

We investigated the production of sung and spoken utterances in a nonfluent patient, CC, who had a severe expressive aphasia following a right-hemisphere stroke, but whose language comprehension and memory were relatively preserved. In Experiment 1, CC repeated familiar song excerpts under four different conditions: spoken lyrics, sung lyrics on original melody, lyrics sung on new but familiar melody, and melody sung to a neutral syllable "la". In Experiment 2, CC repeated novel song excerpts under three different conditions: spoken lyrics, sung lyrics, and sung-to-la melody. The mean number of words produced under the spoken and sung conditions did not differ significantly in either experiment. The mean number of notes produced was not different either in the sung-to-la and sung conditions, but was higher than the words produced, hence showing a dissociation between CC's musical and verbal productions. Therefore, our findings do not support the claim according to which singing helps word production in nonfluent aphasic patient. Rather, they are consistent with the idea that verbal production, be it sung or spoken, result from the operation of same mechanisms.

Expressive language deficits occurring after brain damage, encompassed under the general heading of aphasia, have long been reported (e.g., Broca, 1861). One striking report from clinical settings concerns severely aphasic patients who, having recovered none or few of their speech abilities, are still able to sing previously learned songs with well-articulated and linguistically intelligible words. Such patients, who became aphasic after the removal of the whole left hemisphere (e.g., Smith, 1966) or after stroke (Assal, Buttet, & Javet, 1977; Jacome, 1984; Yamadori & al., 1977), have a very restricted output with respect to spontaneous speech, but seem to be able to recover word articulation with the support of melody. All reports but one (Assal & al, 1977) concern patients with no particular music training. Thus, this ability to sing with words seems to reflect a general trait of cerebral organization.

The classical interpretation of this long-standing observation is that singing familiar songs would depend on right-hemisphere functions, whereas propositional (generative) speech would depend on left-hemisphere functions. Damage to the left hemisphere, therefore, would leave intact the patients' ability to sing previously learned songs, whereas damage to the right hemisphere would impair "automatic" speech and familiar song singing. Some case reports fit with this interpretation (e.g., Speedie, Wertman, Ta'ir, & Heilman, 1993), but some others do not (e.g., case # 2 of Assal, Buttet, & Javet, 1977).

These reports remain descriptive in that they are not substantiated by quantitative behavioural data of patients' production. The only study that did so does not support the idea that music facilitates word production. Cohen and Ford (1995) examined the production of 12 patients who became aphasic after a unilateral left-hemisphere vascular accident. Patients chose three songs from a list of eight songs they had sung in therapy over the previous three months. Patients had to produce the words of these familiar songs under three experimental conditions: Spoken naturally (without any support), spoken with a steady drumbeat accompaniment, and sung accompanied with the melody played on a keyboard. Word intelligibility (i.e., the average number of intelligible words divided by the average duration of each condition) was greater when utterances were spoken, with respect to when sung or spoken accompanied with a drumbeat.

There are, however, a number of shortcomings that prevent firm conclusions to be drawn. For instance, the type and severity of aphasia of the patients were not specified. More importantly, only the group data are reported: These may not be representative of how each patient performed in the different conditions. The averaging of performance may create effects that do not reflect any of the individual performance patterns, or may cancel out effects that would have been significant at the individual level (see Caramazza & McCloskey, 1988). Also, as was suggested by the authors themselves, the word intelligibility index could have been compromised in the rhythm and melody conditions because judges had to listen to recorded speech with musical instruments in the background. Masking effects could thus contribute to the lower intelligibility found in these conditions. Another factor is that the word intelligibility index was only an approximation of the patients' production: Only a random sample taken from each patient in each condition was examined, which rendered the productions not necessarily comparable from one condition to another, or from one patient to another. Furthermore, patients' performance on the melodic dimension of the songs was not assessed. Yet, depending on its complexity, music may perturb rather than facilitate word production. Music may increase word recall provided it is simple and repetitive (Rubin, 1977; Serafine, Crowder & Repp, 1984; Wallace, 1994), but word recall is higher for spoken than for sung words when music is more difficult to learn (Wallace, 1994; Racette & Peretz, 2001). Finally, given that amusia (i.e., a deficit in musical abilities occurring after brain damage) is more often associated to aphasia than not (see Marin & Perry, 1999), the presence of amusia, in some, or all of the patients, cannot be ruled out.

The weakness of the empirical support, or the lack thereof, demands a closer assessment of the claim that music helps word articulation. In particular, the comparison between sung and spoken productions needs more methodological rigor. The question is of theoretical and clinical importance. First, music and language are generally viewed as activities relying on largely separate neural and cognitive processes. Indeed, even though deficits in language and music functions may co-occur after brain damage, it is likely that the association between amusia and aphasia is attributable to the proximity between brain regions responsible for those functions. A number of carefully detailed perceptual studies done with brain-damaged patients have amply documented functional dissociations between language and music: That is, musical abilities may be spared while language functions are impaired, and vice versa, even in songs. Specifically, amusic patients with no aphasia have been described who are still able to recognize and judge words of songs as familiar despite an inability to recognize the corresponding musical song part (Griffiths & al., 1997; Hébert & Peretz, 2001; Peretz, 1996; Peretz, Belleville, & Fontaine, 1997; Peretz, Kolinsky, Tramo & al., 1994). From this perspective, a sparing of the ability to sing words while being unable to speak the very same words would be challenging to the current view that lyrics and melodies are separable entities, even in songs.

Secondly, the very observation of patients being able to sing despite not being able to speak is at the origin of the Melodic Intonation Therapy (MIT), a technique that has been considered as the most promising avenue for aphasia rehabilitation by the American Neurology Association (1994). MIT does not use the singing of familiar songs *per se* as a form of therapy. Rather, it uses intonation patterns that exaggerate the normal melodic content of phrases that gradually vary in complexity as the patient makes progress, with the underlying idea being that musical intonation ability, a form of singing, is a right-hemisphere function. Interpretation of successful recovery from aphasia with the MIT technique was that it facilitated the use of language areas of the right hemisphere, after damage to the language areas in the left hemisphere (Albert, Sparks, & Helm, 1973), or that it increased the role of the right hemisphere in inter-hemispheric control of language (Sparks, Helm, & Albert, 1974). Recent evidence, however, does not support either one of these interpretations (Belin, VanEeckhout, Zibovicius, & al., 1996). Rather, it suggests that right-hemisphere activation would sign the <u>persistence</u> of aphasia rather than its recovery, and that the latter is associated with a reactivation of language-related structures in the left hemisphere.

Theoretical accounts other than those involving hemispheric specialization should thus be considered. In particular, there are alternative explanations regarding why singing would have the potential to facilitate word production. One possible explanation is that sung words are articulated at a slower rate in singing than in speaking. This speed reduction would enable word pronunciation that would otherwise be too rapid. Slowed speech is characteristic of nonfluent aphasias (Geshwind, 1971). Singing generally enhances fluency and word intelligibility of patients with motor speech disorders, such as dysarthria or stuttering, presumably by speed reduction (Cohen, 1988; Colcord & Adams, 1979; Healey, Malard III, & Adams, 1976; Pilon, McIntosh, & Thaut, 1998). Furthermore, it has been shown that syllable lengthening, which is an acoustic correlate of speed reduction in singing, helps nonfluent aphasic patients when they use the Melodic Intonation Therapy: The longer the syllables are, the more phrases are produced by patients (Laughlin, Naeser, & Gordon, 1979). It is probable that syllable chunking and rhythmic anticipation also participate in this advantage of singing over speaking, although their contribution have never been formally assessed.

Another potential contributing factor to the facilitating effect of singing over speaking is that production of familiar songs imposes a reduced demand for language formulation. Familiar songs are overlearned and use non-propositional language. They are encoded as "word strings" that are recalled verbatim (Peretz, Babaï, Lussier, Hébert, & Gagnon, 1995; Wallace, 1994). Moreover, the tight bonding between words and music in songs makes them difficult to separate in memory in normal listeners (e.g., for familiar songs: Hébert & Peretz, 2001; for novel songs: Serafine & al., 1984). The musical part of familiar songs can help to provide access to verbal knowledge when direct access to lexicon is compromised by amnesia (Baur, Uttner, Iimberger, Fels, & Mai, 2000). Conversely, access to song representation in memory can be achieved through access to the speech lexicon when access to music is compromised by amusia (Steinke, Cuddy, & Jakobson, 2001). Because they are strongly connected in memory, producing familiar melodies could help to retrieve the production of words associated with these melodies. Moreover, as familiar songs have been heard and produced repetitively, the mental representation of songs is not only tied to their content (words and music), but also to their motor program pattern. This could explain why automatized formulations such as familiar song words, prayers, and other similar materials such as months of the year and days of the week, are less vulnerable than unfamiliar material to brain damage.

In summary, there is little empirical and theoretical ground to support the claim that singing words can be spared despite severely impaired speech abilities. In the present study, we carry out the first systematic evaluation of word production in a severely nonfluent aphasic patient, by comparing his sung and spoken production of the same utterances. Two experiments examined familiar and novel materials, respectively. Productions were analysed in terms of both words and notes produced, in order to establish whether or not music imposes a load on memory and production, as it can occur in text recall.

Case Description

Neurological History

The patient, CC, is a right-handed retired policeman (with 12 years of school education) who was 60 when he suffered from unilateral cerebral damage caused by a right sylvian thrombosis. On the morning of May 23rd, 1997, his wife found him lying on the bed, with left superior hemiplegia and aphasia. On admission, the neurological examination further revealed a left facial paresis as well as paresis of the left arm and leg and left hemianopsia. Head CT scan and more recently MRI images (see figure 1) revealed a right temporo-fronto-parietal hypodensity involving cortical and subcortical regions extending to the internal capsule, destruction of the temporal pole, atrophy in the region of the sylvian fissure, and ventricular enlargement. There was no sign of intra-cranial blood or hypertension. Given the atypical occurrence of aphasia following right-hemisphere damage in a right-handed man, a control CT-scan and a MRI examination were carried out and confirmed that there was no evidence of cerebral damage other than the one initially found on the right side.

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insert Figure 1 about here

CC scored 100% right-handed on the Edinburgh handedness Inventory (Oldfield, 1971), including eye dominance: When he worked as a police officer, he used his right eye to properly align his weapon to the target.

CC was admitted to rehabilitation for twelve months, where he underwent physical, occupational, and speech therapy. On the day of discharge, he had recovered much of his physical abilities (he was able to walk with a cane) but he was still severely aphasic.

Neuropsychological Assessment

A summary of CC's cognitive functioning is available in Table 1. Some of the tests were administered twice, coinciding approximately (within a two-month period) with the times when the experimental testing was carried out. The first testing was done about six months post-infarct, and the second one about three years later. Mini-mental state examination (Folstein, Folstein, & McHugh, 1975), as well as Verbal IQ and Verbal memory assessment were not possible due to his severe expressive aphasia. CC' scores on nonverbal IQ and MQ (WAIS-R and WMS-R) were slightly below average. This was attributable to a deficit in attention and slowness in information processing, and is compatible with the severity of aphasia displayed by CC. His performance was characterized by an impaired verbal (but not nonverbal) working memory. Performance on long-term and semantic memory tests was normal.

Insert Table 1 about here

Language Assessment

Spontaneous speech was severely impaired both quantitatively and qualitatively, and characterised by aborted sentences, filling words, neologisms, and phonemic paraphasias. A summary of CC's language functioning is given in Table 2. Language assessment was carried out with some of the sub-tests from a French adaptation of the Boston Diagnostic Aphasia Examination (Mazaux & Orgogozo, 1981). However, most of the language tests were drawn from the MT-86ß Aphasia Battery (Nespoulous, Lecours, Lafond & al., 1992), for which normative data in French are available (Béland & Lecours, 1990; Béland, Lecours, Giroux & al., 1993). Overall, performance showed a discrepancy between receptive and expressive language abilities. There was some improvement over time on both naming and verbal fluency tests, but CC's performance remained very much below average. Testing was effortful, and error types were consistent with those found in spontaneous speech. Out of a total of 55 errors, most were omissions (34.5%), and the rest were distributed among paraphasias (20%, most often semantic, e.g., elikɔptɛʀ/*helikɔptər* becomes kamjɔ̃/*trʌk*), perseverations (16.4%), neologisms (9.1%, e.g., si/*sɔ* becomes mekuʀ), phonemic transformations (10.9%, 3.4% of which became lexical, e.g., pɛɲ/*koum* becomes bɛɲ/*dounʌt*, pelikã/*pelikən* becomes melika), and other incomplete responses (9.1%, e.g., likɔʀn/*junikɔrn* becomes lik). In contrast, automatic speech was well preserved except for a few phonemic transformations, with normal performance on most tests involving series.

Insert Table 2 about here

Comprehension was impaired, but less severely so than expression, and related in great part to CC's working memory problems. For instance, in the Token test, his performance was 14/15 on the first 15 items (five words and less), and degraded promptly when the instructions were eight words long or over. Repetition involving words and short phrases was normal and dropped when sentences involved eight words or more. The diagnosis was crossed mixed aphasia, with a more severe deficit on the expressive side.

Musical Assessment and Automatized Speech

CC was not a formally trained musician, but had been an amateur singer all his life (he still loves to sing), both in solo and in choirs. CC provided us with tapes containing live performance of his singing before his accident, and therefore we are confident that he had excellent pre-morbid singing abilities. A preliminary musical assessment on the Montreal battery of Evaluation of Amusia (MBEA; Liégeois-Chauvel, Peretz, Babaï, & al., 1998) indicated that CC was within the normal range on all subtests, except in the Scale discrimination condition and Incidental memory test, where CC performed just slightly below the controls, and within, or just above, 1SD from the controls' mean. Controls were nine elderly with a mean age of 58.2 (range: 55-64) and 13.9 years of education on average (range = 7-20). We assessed CC's memory for highly familiar songs by asking him to make a familiarity judgement for 20 tunes (without lyrics) presented in random order, half being familiar and the other half novel (see Table 3). CC could classify correctly 18 out of the 20 tunes.

Insert table 3 about here

His ability to retrieve lyrics of well-known songs was assessed by examining whether or not CC could continue songs when given the first part. He was given the first half-phrase of song under three conditions, that is, either sung on a neutral syllable, with the lyrics spoken, or sung with lyrics and music. He was asked to carry on in the same manner (that is, to continue either the tune only, the lyrics only, or the song): CC could sing the tunes on a neutral syllable without any difficulty (20/20), but could not continue the lyrics of any of the songs (0/20). When given the songs, he could accurately sing about half of them with words and music, either perfectly or with some errors (14/20).

His automatic speech was preserved for prayers, but not for proverbs, as he could recover the last part of only four out of 18 very popular sayings (yet in seven instances CC missed one or two words only).

In sum, despite very impaired spontaneous speech abilities and severe expressive aphasia, this initial assessment established that CC was not amusic. Cueing him with songs (words and music) seemed to help him continue the lyrics, but it was unclear if the music would help him to retrieve the words of songs under more controlled situations. Since his ability to repeat was relatively preserved, repetition was used in the following experiments.

General Method

Participants:

CC: The patient, CC, participated in Experiments 1 and 2. The same materials (with some exceptions, as described below) served in two testing sessions at two different time points (Session 1 = 6-months post-infarct; Session 2 = 33 months post-infarct).

Controls: Control data for the two experiments were obtained once from four healthy retired policemen, with no history of neurological or psychiatric diseases, at the time of Session 2 for CC. Their socio-economic backgrounds, handedness, and age closely matched those of CC (mean age = 61.8 years; range = 59-66). None of them had formal musical training, and they were all singers in a police amateur choir. All subjects (CC and Controls) gave their informed consent to all tests administered.

Procedure for CC

The excerpts were sung to the patient by the experimenter. The live procedure ensured good contact with CC and a dynamic environment, and enabled also the use of visual as well as auditory cues. This situation, therefore, placed CC in the best testing conditions. CC was instructed to repeat each excerpt immediately after hearing it. The whole testing session was recorded using a portable Digital Audio Tape recorder.

Procedure for Controls

All the excerpts from testing session 2 (i.e., excerpts as sung by the experimenter to CC) were extracted from the DAT tape, and presented to controls. In other words, controls heard the excerpts as they were actually sung or spoken to CC. They were placed, however, in slightly more difficult testing conditions since they were not presented with a live performance and hence, could not use visual cues. They were tested individually, and their own testing session was also recorded.

Data scoring.

All the productions were saved in individual computer sound files. Two musically trained judges made independent quantitative and qualitative scorings of both texts and melodies.

For text, the percentage of correctly repeated words was calculated. Percentage of words, rather than syllables, was considered as the dependent variable, since numbers of syllables sometimes differ between sung and spoken renditions. Elisions (equally present in both spoken and sung versions) were considered as part of the word to which they were attached.

Criteria for considering a word as "incorrect" were the following: Any change from the originally presented words (see below the type of change), omissions, or inversion of words. A point was withdrawn from the raw score for any addition of words or (unintelligible) word string at the beginning or within the utterance. Errors were classified according to six relevant linguistic categories: Phonemic, lexical, omissions, inversions, additions, and neologisms/unintelligible.

For melodies, the percentage of correctly repeated notes was calculated. Out-of-tune or missing notes were considered as mistakes. One point was withdrawn for each additional note, and for rhythmic mistakes.

Experiment 1: Familiar Song Production

In Experiment 1, we investigated CC's performance on familiar songs. In Session 1, we were particularly interested in finding out whether or not singing the original familiar song (original words with original music -matched songs) would be better reproduced than singing the familiar words to an equally familiar, but different, melody (mismatched songs). In other words, we were interested in assessing the effect of singing per se in comparison with singing the original songs. If singing per se were a facilitator for word production, either by virtue of speed reduction or some other means, then singing familiar words should yield comparable performance whether words were sung to the original or to a mismatched melody. In Session 2, two conditions were added, that is, a spoken condition where CC had to say the words of the songs in a natural manner, and a condition where he had to sing the melodies of the songs on a neutral syllable "la". If singing helps to produce words accurately, then the sung versions should yield higher performance than the spoken ones.

Materials

Sixteen pairs of highly familiar songs were selected from a repertoire of childhood and traditional songs (Peretz, Babaï, Lussier & al., 1995). Excerpts were 9.5 notes on average (range: 7-16 notes), and 6.7 words (range: 4-11 words). Two long excerpts were shortened for Session 2, reducing the average number of notes to 8.5 notes (range: 7-11) and the number of words to 5.9 (range: 4-7).

Excerpts are presented in Appendix A (available at *Brain* online). The song of each given pair was interchangeable in terms of text and melody with another song, thus generating two new, mismatched, songs, with every pair of familiar songs (see Figure 2).

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insert Figure 2 about here

There were two experimental conditions in Session 1. In the first condition, the original songs (original text and melody) were sung (mean duration = 4.47 sec, SD = 1.21, range = 2.7 - 7.4). In the second condition, the mismatched songs (text and melody interchanged) were sung (mean duration = 4.54 sec, SD = 1.35, range = 2.9 -7.7 sec). There was no significant difference between the durations of these versions, $t(14) = -.22$, $p = .83$. In Session 2, two "isolated" conditions were added, that is, the spoken version (mean duration = 2.52, SD = 0.61, range = 1.7-3.9 sec) and the melody on the neutral syllable "la" (mean duration = 4.35 sec, SD = 1.14 sec, range = 2.9- 6.9). As expected, the duration of productions were significantly different, $F(3,42) = 14.18$, $p<.001$. The Spoken versions were produced at a faster rate than the other versions ($p<.001$), but the latter did not differ from each other (all ps > .05). Thus, on average, the spoken versions were 1.67 times faster than the sung versions.

Procedure: In Session 1 (CC only), trials including the Matched and Mismatched melodies used with a given set of lyrics were presented in pairs. That is, the same lyrics were presented twice in a row, once with the familiar and once with the mismatched melody, in a counter-balanced order.

In Session 2 (CC and Controls), the spoken versions were added. Each condition (Matched, Mismatched, and Spoken) was split into three blocks of five or six excerpts, and organised in such a way that order of presentation of these three conditions was counter-balanced across excerpts. A short pause followed every block. The melodies on the syllable "la" were presented in one single block at the end of the testing session.

Results and Comments

Inter-rater Agreement

Inter-rater agreements were calculated separately for Language and Music for CC and his controls (collapsed across Sessions). For Language (Spoken and Sung versions), the inter-rater correlations were r (76) = .98, p<.001 for CC, and 1 for Controls. For Music (Matched and Mismatched versions), the inter-rater correlations were r (77) = .98, p <.001 for CC, and r (174) = .95, p <.001 for Controls. Overall, there were very few words and notes for which no consensus could be reached among raters (between 0% and 3.4% of productions), and those were withdrawn from the analyses.

The percentage of correctly repeated words and notes for each excerpt in each Condition served as dependent variables. Data are shown in Table 4. Due to a technical error in Session 2, one song was removed from the analyses for that session.

Insert Table 4 about here

CC's performance.

An ANOVA was conducted with Excerpt as the random factor, and Session (1 vs. 2), Condition (Music vs. Language) and Version (Matched vs. Mismatched) as within-item factors. This analysis revealed a significant main effect of Condition, $F(1,14) = 27.40$, $p < .001$, with an overall better performance on Music than on Language (with 94.1% and 79.2%, respectively). More interestingly, the analysis also yielded a significant interaction between Condition and Version, $F(1,14) = 10.33$, $p < .01$. Performance between Matched and Mismatched versions did not differ for music (with 91.9% and 96.3% for Matched and Mismatched, respectively, $p > .05$), but did on Language (with 86.4% and 72.0% for Matched and Mismatched, respectively, $p < .01$). Thus, CC produced more words when music and lyrics were set in their original combination.

CC vs. Controls

The following analysis compared CC's performance in Session 2 with the ones of his Controls. CC's performance was well within the range of his Controls' in the Music condition with 91.7% (range of controls: 70.6-98.6%), but not in the Language condition, where CC performed at 75.2% and his Controls reached perfect performance in the three versions. As normality of distributions could not be assumed, nonparametric tests were run to examine the performance of CC and of his Controls separately. Friedman's tests revealed that CC's performance in the three versions did not differ from each other in the Music, $\chi2(2) = 1.62$, $p = .45$, nor in the Language condition, $\chi2(2) = 2.47$, $p = .29$. This pattern of performance was also found for the Controls, yet with a trend for Matched songs to yield better performance than Mismatched songs in the Music condition, with $\chi 2$ (2) = 5.087, p =.08. The Controls' performance in the Language condition was at ceiling in all three versions.

Error types for CC are shown in Table 5. Because of the small number of errors in each category, $\chi 2$ could not be computed. However, the error pattern looks similar across the three conditions (Spoken, Matched, and Mismatched), and is consistent with the language assessment tests. That is, errors are mostly characterized by omissions, phonemic (e.g., mulɛ̃/*windmil* becomes numɛ̃) and lexical (e.g., mɔ̃/*mai* becomes tɔ̃/*jɔr*) errors, with the exception of inversions, which occurred more often in the spoken version than in the sung versions.

Insert Table 5 about here

Overall, results of this experiment show a dissociation between CC's musical and language abilities, and show that CC's performance remained similar more than two years after his brain infarct. More importantly, results do not support the claim that singing words yields better performance than speaking the same words, even though motor programming of sung versions enjoyed a privileged status in memory over spoken versions. CC's performance in the language condition, however, was overall quite high, in that CC could repeat correctly, on average, between 65% and 86% of the words of the song excerpts, depending on the condition involved. Although this performance on language was still very much below the perfect performance of his controls, this was an outstanding achievement given his very impaired spontaneous speech abilities. This underlines the contrast between generative speech and rote memory: CC's spontaneous speech is very poor, yet for a number of familiar song excerpts he could nevertheless produce 100% of the words accurately. This is a very striking contrast if considered in isolation. It supports the idea that songs are encoded as highly automatized word strings in memory.

What our results demonstrate is that across a pool of highly familiar songs, word production is similar across speaking and singing. Therefore, neither the act of singing or the presence of the musical part of the songs help CC to produce words more accurately, although CC was generally more fluent with this material than in everyday spontaneous speech. This was also supported by the findings that the three versions, that is, Matched, Mismatched, and Spoken versions, yielded comparable performance. Therefore, singing per se, that is, singing words onto an equally familiar, but not the original, melody, was not any better for word production over speaking. It should be noted that producing words and music was not detrimental to CC's production of notes, since singing the tunes on a neutral syllable yielded the same performance, in terms of number of notes, as singing with lyrics. This was also true for CC's Controls.

Experiment 2: Unfamiliar Song Production

In Experiment 2, CC was presented with novel songs. Thus, the sung versions had no particular advantage over the spoken versions, given that none had ever been previously heard or produced. As in the previous experiment, CC had to repeat each novel excerpt under the different experimental conditions (i.e., sung, spoken, sung-to-la melody) after having heard it. If singing improves word production, repetition of sung words should be better than spoken words. On the other hand, if sung and spoken production stem from the same processes, performance for sung words should not differ significantly from the one for spoken words.

Materials

Sixteen unfamiliar songs were selected from a repertoire of childhood songs (Hachette Jeunesse, 1995). Excerpts were 9.4 notes long (range: 7-14 notes), and 5.6 words (range: 4-8 words) on average. Three excerpts were shortened for the testing session 2, therefore reducing the average number of notes to 8.2 (range: 6-13) and the number of words to 4.9 (range: 4-7). Excerpts are presented in Appendix A. Each excerpt served in three different experimental conditions: In the first condition, the melodic part of the song was sung on the neutral syllable "la" without accompaniment (mean duration = 3.62, SD = 0.86, range =2.55-5.42). In the second condition, the text of the songs was spoken in a natural manner (mean duration = 2.22 sec, SD = 0.59, range = 1.2-3.72 sec). In the third condition, the song (text and melody) was sung without accompaniment (mean duration = 3.54 sec, SD = 0.76, range = 2.55-5.42 sec). An ANOVA on durations taking Sessions (1 vs. 2) as the between-items factor, and Versions (Spoken, Sung, Sung-to-“la”) as the within-items factor yielded no significant effect of Session ($F<1$), but a significant main effect of Version, $F(2,60) = 185.29$, $p<.001$. The mean duration for the Spoken version was shorter than for the two other versions ($p<.01$), and the latter did not differ from each other ($p = .30$, by post-hoc comparisons). Again, on average, the spoken version was produced 1.6 times faster than the other conditions.

Procedure: In Session 1 (CC), conditions 1 and 2 (i.e. Isolated) were presented in two blocks of eight excerpts presented in a random order. Half of the spoken excerpts were presented first, followed by half of the melodies sung on the syllable “la”, followed by a short pause. Finally, the songs were presented in one single block. In Session 2 (CC and Controls), the three conditions were split into three blocks of five or six excerpts. These were presented in a counterbalanced order. A short pause followed every block. The melodies on the syllable “la” were presented in one single block at the end of the testing session.

Results and Comments

Inter-rater Agreement

Inter-rater agreements were calculated separately for Language and Music for CC and his controls (collapsed across Sessions), and were again very high. For Language (Spoken and Sung versions), the inter-rater correlations were r (62) = .95, $p<.001$ for CC, and r (126) = .99, $p<.001$ for Controls. For Music (Sung-to-“la” and Sung versions), the inter-rater correlations were r (62) = .96, $p<.001$ for CC, and r (126) = .95, $p<.001$ for Controls. The very few words and notes for which no consensus could be reached among raters (between 0.8% and 8.6% of productions) were withdrawn from the analyses.

The percentage of correctly repeated words and notes for each Excerpt in each Condition served as dependent variables. Results are shown in Table 6.

Insert Table 6 about here

CC's performance.

An ANOVA was conducted with Excerpt as the random factor, and Sessions (1 vs. 2), Condition (Music vs. Language) and Version (Isolated --Sung-to-"la" or spoken-- vs. Sung) as within-item factors. This analysis revealed a significant effect of Condition, F (1, 15) = 22.22, p <.001, the Music condition yielding much better overall performance than the Language condition (with 84% vs. 53.9%, respectively). Although there was a trend for overall performance to improve from Session 1 to Session 2 (64.4% vs. 73.4%, respectively), it was not significant, F (1,15) = 3.77, p <.08. There was no other significant or near-significant main effect or interactions.

CC vs. Controls.

A second analysis was run to compare CC's performance in Session 2 with the ones of his controls. Once again, CC performed in the range of his controls in the Music condition with 87.2% (range of controls: 77.8-96.8%), but not in the Language condition with 60% (range of controls: 99.1 - 100%). Nonparametric tests revealed that CC's performance did not differ among the two versions in the Music condition, $\chi2(1) = 0.00$, $p<1.00$, or in the Language condition, $\chi2(1) = 1.33$, $p=.25$. The same pattern was found for Controls, with $\chi2(1) = 1.60$, $p=.21$ in the Music condition, and $\chi2(1) = 1.00$, $p=.32$ in the Language condition. Thus, the performance of both CC and his Controls did not differ from one version to another (i.e., Isolated -- Spoken or Sung-to-"la" vs. Sung).

The scores for each error type were collapsed across conditions (Spoken vs. Sung) and Sessions (1 vs.2). The error types were similar across the Sung and Spoken conditions, and did not differ statistically, $\chi2 = .14$, ns (see Table 5).

The results of this experiment show that CC did not perform better when singing than when speaking, despite intact musical abilities. When presented with novel phrases, CC's performance on Language was lower than his Controls' irrespective of the version produced. The reduced speed, regularity, or syllable chunking imposed by singing seemed not sufficient to produce a better performance in sung versions than in spoken versions. Rather, there is a (nonsignificant) trend for the music to impose an additional burden on CC's ability to produce words, as his performance tended to be poorer in the sung condition than when there was no music associated.

The important aspect to bear in mind is that CC's striking ability to produce song excerpts was unsuspected from his spontaneous conversation. Thus, our findings do not contradict the clinical observation that patients who cannot sustain a spontaneous conversation can nevertheless sing. What our results demonstrate, however, is that patients who can sing can also articulate words of those songs, if put in the right conditions to do so.

However, having previous knowledge of the songs made it easier for CC to repeat the lyrics, whereas it did not change his performance on Music. This was verified by an ANOVA that compared CC's performance (in Session 2) on Familiar and Unfamiliar materials, as a function of Conditions (Music vs. Language) and Versions (Isolated -- Spoken or Sung-to-"la"-- vs. Sung). As expected, the interaction between Material and Condition was significant, $\underline{F}(1,30)= 4.26$, $\underline{p}<.05$: CC's performance on Music did not differ across Material, with 87.7% and 87.2% on familiar and unfamiliar materials, respectively ($\underline{p}>.05$), but differed on Language, with 79.3% and 60% for familiar and unfamiliar materials, respectively ($p<.01$). This confirms the fact that CC is at ease with music, either familiar or unfamiliar, and that familiar song representations encoded in his long-term memory helped him to produce the words originally associated with the music.

GENERAL DISCUSSION

The main finding from the present study shows that singing does not facilitate word articulation in the case of a nonfluent aphasic patient. This applies to both pre-learned and novel songs. Music did not play a facilitating role in word production, by virtue of either mechanical constraints including speed reduction or cognitive load, such as syllable chunking and rhythmic anticipation. Rather, word articulation seems to be governed by mechanisms that are insensitive to the mode of expression, be it sung or spoken.

CC represents a classical instance of aphasia without amusia: He performed normally when he had to produce the musical parts of songs, but at a much lower level when he had to repeat the words, either sung or spoken. Such a dissociation between performance on parts of the <u>same stimuli</u> (i.e., songs) consisting of both a verbal and a musical part, is not banal. Indeed, aphasia often occurs jointly with amusia, most likely because a natural lesion is likely to affect cognitive functions such as music and language that depend on systems lying in close proximity in the brain. CC is yet another case demonstrating a dissociation between music and language skills (e.g., Hébert & Peretz, 2001; Peretz, Belleville, & Fontaine, 1997; Peretz, Kolinsky, Tramo, & al., 1994; Steinke, Cuddy, & Jakobson, 2001). The present case study of CC serves as the first demonstration that language and music can be dissociable at the level of production. To date, all previous reports have involved perception and memory tasks. Thus, CC's results indicate that different networks subserve music and language, and that even in songs, the musical and the language parts are processed by independent mechanisms.

Another important contribution of this study is from a methodological perspective. We showed that when music and speech are compared under identical testing conditions they maintain their functional autonomy. This involved comparing production of the same utterances in both speech and singing. In most prior studies, spontaneous speech was simply contrasted with singing well-known songs. From this perspective, CC is not unique; he could also reproduce the words of familiar songs with few errors and quite fluently. Thus, CC's results are consistent with the classical claim of nonfluent aphasic patients still being able to sing. The contrast between generative and rote memory, as exemplified by his spontaneous speech and his song production, respectively, is indeed remarkable. Despite the fact that the mean number of words correctly repeated was not significantly different when singing than when speaking, CC's singing yielded to the raters a feeling of fluency that was particularly strong. This impression of fluency, presumably produced by legato (i.e., no pauses between words), is not captured in the overall scores presented in this study. Unfortunately, fluency is poorly defined, and its corresponding acoustical cues are unknown (Gordon, 1998). Therefore, the impression of fluency in singing certainly contrasts with the limited and jerky spontaneous speech output of nonfluent aphasic patients. However, a rigorous comparison between sung and spoken productions yields a quite different picture: When a nonfluent aphasic patient is able to sing a familiar song with words, he is <u>also</u> able to produce the corresponding words in a spoken fashion. The same is true for novel materials for which there were no pre-existing mental representations.

If singing does not facilitate word articulation, then the MIT should perhaps no longer be considered as key a tool in this endeavour. However, as mentioned previously, there are additional benefits that the MIT may provide. For instance, it has been recently suggested that a treatment emphasizing the rhythmic attributes of target utterances improved repetition to a greater degree than one emphasizing their melodic attributes (Boucher, Garcia, Fleurant, & Paradis, 2001). Similarly, reduction of speech rate, improvement of vocabulary, and maintenance of proper breathing, may all contribute to the improvement of spontaneous speech. Extra-linguistic aspects such as maintaining motivation and high spirits in patients after brain damage, by feeling competent in singing should also be taken into consideration. There remains a great need for formal assessments of the MIT interventions, along with detailed information about patients to be included.

A further aspect of the study that is worthy of discussion is the fact that CC became aphasic consequent a right-hemispheric lesion. The question is to what extent a reversed brain organization for language (in a right-hander) has implications for song performance. At the behavioural level, the type of aphasia displayed by CC is classic, in that CC displays a pattern of performance that is typical for a nonfluent aphasic patient. In support of this claim, Coppens and colleagues (Coppens, Hungerford, Yamaguchi, & Yamadori, 2002) made a thorough analysis of published crossed aphasia cases, and concluded that the symptomatology of aphasia displayed by these patients (be it categorised as mirror-image or anomalous aphasia type) does not differ from the one displayed by left-hemisphere damaged patients. In addition, following the criteria defined by the American Neurology Association (1994) based on phenomenology rather than hemisphere of lesion, CC may have been a choice candidate for the Melodic Intonation Therapy, especially since he could sing without difficulty. CC's typical profile suggests that his performance in our experiments is representative of the performance of nonfluent aphasic patients in general. Thus it is expected that our findings would be replicated in other patients with similar types of language impairments. At the very least, our study provides a robust way of testing this prediction in other patients.

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References

Albert ML, Sparks RW, Helm NA. Melodic Intonation Therapy for Aphasia. Arch Neurol 1973; 29: 130-1.

Anonymous. Assessment: Melodic Intonation Therapy. Reports of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. Neurology 1994; 44: 566-8.

Assal G, Buttet J, Javet RC. Aptitudes musicales chez les aphasiques. Rev Med Suisse Romande 1977; 97: 5-12.

Baur B, Uttner I, Ilmberger J, Fels G, Mai N. Music memory provides access to verbal knowledge in a patient with global amnesia. Neurocase 2000; 6: 415-21.

Béland R, Lecours AR. The MT-86ß Aphasia Battery: a subset of normative data in relation to age and level of school education. Aphasiology 1990; 4: 439-62.

Béland R, Lecours AR, Giroux F, Bois M. The MT-86ß Aphasia Battery: a subset of normative data in relation to age and level of school education. (Part II). Aphasiology 1993; 7: 359-82.

Belin P, Van Eeckhout P, Zibovicius M, Remy P, François C, Guillaume S, Chain F, Rancurel G, Samson Y. Recovery from nonfluent aphasia after melodic intonation therapy: A PET study. Neurology 1996; 47: 1504-11.

Broca P. Remarques sur le siège de la faculté du langage articulé suivis d'une observation d'aphémie. Bulletin de la Société d'Anatomie 1861; 6: 330-364.

Boucher V, Garcia LJ, Fleurant J, Paradis J. Variable efficacy of rhythm and tone in melody-based interventions: Implications for the assumption of a right-hemisphere facilitation in non-fluent aphasia. Aphasiology 2001; 15: 131-149.

Caramazza A, McCloskey M. The case for single-patient studies. Cognitive_Neuropsychology 1988; 5: 517-27.

Cohen NS. The use of superimposed rhythm to decrease the rate of speech in a brain-damaged adolescent. J Music Ther 1988; 25: 85-93.

Cohen NS, Ford J. The effect of Musical Cues on the nonpurposive speech of persons with aphasia. J Music Ther 1995; 32: 46-57

Colcord RD, Adams MR. Voicing Duration and Vocal SPL Changes Associated With Stuttering Reduction During Singing. J Speech Hear Res 1979; 22: 468-79.

Coppens, P, Hungerford S, Yamaguchi S, Yamadori A. Crossed aphasia: An analysis of the symptoms, their frequency, and a comparison with left-hemisphere aphasia symptomatology. Brain Lang 2002; 83: 425-463.

Geshwind N. Current concepts: aphasia. N Eng J Med 1971; 284: 654-6.

Gordon JK. The fluency dimension in aphasia. Aphasiology 1998; 12: 673-88.

Griffiths TD, Rees A, Witton C, Cross PM, Shakir RA, Green GG. Spatial and temporal auditory processing deficits following right hemisphere infarction. A psychophysical study. Brain 1997; 120: 785-94.

Healey EC, Mallard III AR, Adams MR. Factors contributing to the reduction of stuttering during singing. J Speech Hear Res 1976; 19: 475-80.

Hébert S, Peretz I. Are text and tune of familiar songs separable by brain damage? Brain Cogn 2001; 46: 169-75.

Howard D, Patterson K. Pyramids and Palm Trees. Thames Valley Test Company ; 1992.

In collaboration: Les plus belles chansons du temps passé. Hachette Jeunesse; 1995.

Laughlin SA, Naeser MA, Gordon WP. Effects of three syllable durations using the melodic intonation therapy technique. J Speech Lang Hear Res 1979; 22: 311-20.

Marin O, Perry D. Neurological aspects of music perception and performance. In: Deutsch D, ed. The Psychology of Music. San Diego (2nd Ed.): Academic Press; 1999, 653-724.

Mazaux JM, Orgogozo JM. BDAE-F. Boston Diagnostic Aphasia Examination. Issy les Moulineaux : Éditions Scientifiques et Psychologiques; 1981.

Nespoulous JL, Lecours AR, Lafond D, Lemay A, Puel M, Joanette Y, Cot F, Rascol A. Protocole Montréal-Toulouse d'examen linguistique de l'aphasie. MT 86 Module Standard Initial: M1 ß. 2nd edition revised by Renée Béland and Francine Giroux (L'ortho-edition, Isbergues, France); 1992.

Oldfield RC. The assessment and analysis of handedness: The Edinburgh inventory. Neuropsychologia 1971; 9: 97-113.

Peretz I. Can we lose memories for music? The case of music agnosia in a nonmusician. J Cog Neur 1996; 8: 481-496.

Peretz I, Belleville S, Fontaine F. Dissociations entre musique et langage après atteinte cérébrale: un nouveau cas d'amusie sans aphasie. Can J Exp Psychol 1997; 51: 354-67.

Peretz I, Babaï M, Lussier I, Hébert S, Gagnon L. Corpus d'extraits musicaux: indices relatifs à la familiarité, à l'âge d'acquisition et aux évocations verbales. Can J Exp Psychol 1995; 49: 211-38.

Peretz I, Kolinsky R, Tramo M, Labrecque R, Hublet C, Demeurisse G, Belleville S Functional dissociations following bilateral lesions of auditory cortex. Brain 1994; 117: 1283-1301.

Pilon MA, McIntosh KW, Thaut MH. Auditory vs. visual speech timing cues as external rate control to enhance verbal intelligibility in mixed spastic-ataxic dysarthric speakers: a pilot study. Brain Inj 1998; 12: 793-803.

Racette A, Peretz I. Does music help to recall lyrics? Paper presented at the Canadian Society for Brain, Behaviour, and Cognitive Science Meeting in Quebec city, Canada; June 2001.

Riddoch MJ, Humphreys GW. Birmingham object recognition battery. Hillsdale: Lawrence Erlbaum associates Publishers; 1993.

Rubin DC. Very long-term memory for prose and verse. Journal of Verbal Learning & Verbal Behavior 1977; 16: 611-21.

Serafine ML, Crowder RG, Repp BH. Integration of melody and text in memory for songs. Cognition 1984; 16: 285-303.

Signoret JL. Batterie d'efficience mnésique. BEM144. Paris; Elsevier: 1991.

Smith A. Speech and other functions after left (dominant) hemispherectomy. J Neurol Neurosurg Psychiatry 1966; 29: 467-471.

Sparks R, Helm N, Albert M. Aphasia rehabilitation resulting from melodic intonation therapy. Cortex 1974; 10: 303-316.

Speedie LJ, Wertman E, Ta'ir J, Heilman KM. Disruption of automatic speech following a right basal ganglia lesion. Neurology 1993; 43: 1768-1774.

Steinke WR, Cuddy LL, Jakobson LS. Dissociations among functional subsystems governing melody recognition after right hemisphere damage. Cogn Neuropsych 2001; 18: 411-437.

Wallace WT. Memory for Music: Effect of Melody on Recall of Text. J Expe Psychol Learn Mem Cogn 1994; 20: 1471-1485.

Warrington EK. Recognition memory test. Winsdsor : NFER-Nelson ; 1984.

Yamadori A, Osumi Y, Masuhara S, Okubo M. Preservation of singing in Broca's aphasia. J Neurol Neurosurg Psychiatry 1977; 40: 221-224.

Table 1.

CC's performance on intelligence and memory assessments in Session 1 (6 months post-infarct) and in Session 2 (33 months post-infarct).

	Session 1	Session 2
Performance IQ	75	80
Picture completion*	7	8
Picture arrangement*	5	6
Block design*	8	10
Object assembly*	8	8
Digit symbol*	2	6
Nonverbal MQ	92	81
Working memory		
Digit span (forward/backward)	5/2	4/2
Visuo-spatial span	5	5
Word span	3	3
Long term memory		
BEM 144 (immediate and differed recognition; Signoret, 1991)	24/24	24/24
Facial recognition (Warrington, 1984)	46/50	44/50
Rey figure immediate recall*	9	12
Semantic memory		
Pyramids and Palm trees test (Howard & Patterson, 1992)	-	46/50
BORB **(Riddoch & Humphreys, 1993)**	-	36/40
Picture-word association	-	24/32
Real-unreal judgements Hard	-	30/32
Real-unreal judgements Easy	-	30/32
Item match	-	29/30
Association match		

* Scores scaled according to age.

Table 2.

CC's performance on linguistic assessments in Session 1 (6 months post-infarct) and 2 (33 months post-infarct).

	Session 1	Session 2
Boston Diagnostic Aphasia Examination		
Expression		
Naming	5/60 Severity 1	16/60 Severity 2
Automatized speech		
Digits 1 to 10	n	n
Days of the week	n	n
Months of the year	n	n
Words of the familiar song "Au clair de la lune"	n -	___
Melody of the familiar song "Au clair de la lune"	n	___
MT-86 ß Aphasia Battery		
Expression		
Naming	0/31	16/31
Verbal fluency	2	9
Repetition		
High-and Low- frequency words and nonwords	24/25	25/25
Short sentences (4 words)	1/1	1/1
Long sentences (8-10 words)	0/2	0/2
Oral Comprehension		
Word- and sentence picture matching	32/47	___
Body-part identification under oral instruction	6/8	___
Body-part identification under written instruction	4/8	___
Object manipulation	2/8	___
Reading		
Word reading	13/30	___
Token test	17.5/36	___

n= normal performance; n - = production below normal, i.e., with phonemic transformations.

Table 3.

CC's performance on various musical tests and automatized speech (other than the ones involved in the language assessment).

	CC	Controls' mean (range)
Musical tests		
Montreal Battery of Evaluation of Amusia		
Lexical	19/20	19.7/20 (18-20)
Scale	24/30	26.4/30 (25-29)
Contour	22/30	26.1/30 (22-29)
Interval	23/30	25/30 (21-28)
Rhythm	26/30	28.8/30 (22-30)
Meter	25/30	23.7/30 (21-27)
Incidental memory	24/30	27.7/30 (26-30)
Familiarity judgement	18/20	—
Continuation of familiar songs:		
Lyrics	0/17	—
Tune	20/20	—
Song	14/20	—
Automatized speech		
Prayers	3/3	—
Proverbs	4/18	—

Table 4.

Results for familiar songs (Experiment 1).

	Music			**Language**		
	CC Session 1	CC Session 2	Controls	CC Session 1	CC Session 2	Controls
Isolated	-	89.8%	94.9% (85.3-98.4)	-	72.2%	100%
Matched	99.0%	85.6%	96.2% (90.3-98.3)	87.2%	86.5%	100%
Mismatched	95.0%	97.8%	90.5% (70.6-98.6)	78.4%	66.9%	100%

Table 5.

Error types for familiar (Experiment 1) and unfamiliar (Experiment 2) songs, averaged across session.

	Phonemic	Lexical	Omissions	Additions	Inversions	Neologisms/ unintelligible
Familiar						
Spoken	15%	15%	5%	30%	30%	5%
Matched	16.7%	20.8%	33.3%	20.8%	0%	8.3%
Mismatched	11.3%	41.5%	30.2%	7.5%	5.7%	5.7%
Unfamiliar						
Spoken	18.5%	8.6%	32.1%	7.4%	17.3%	16.1%
Sung	20.6%	20.6%	31.5%	9.6%	6.8%	10.9%

Table 6.

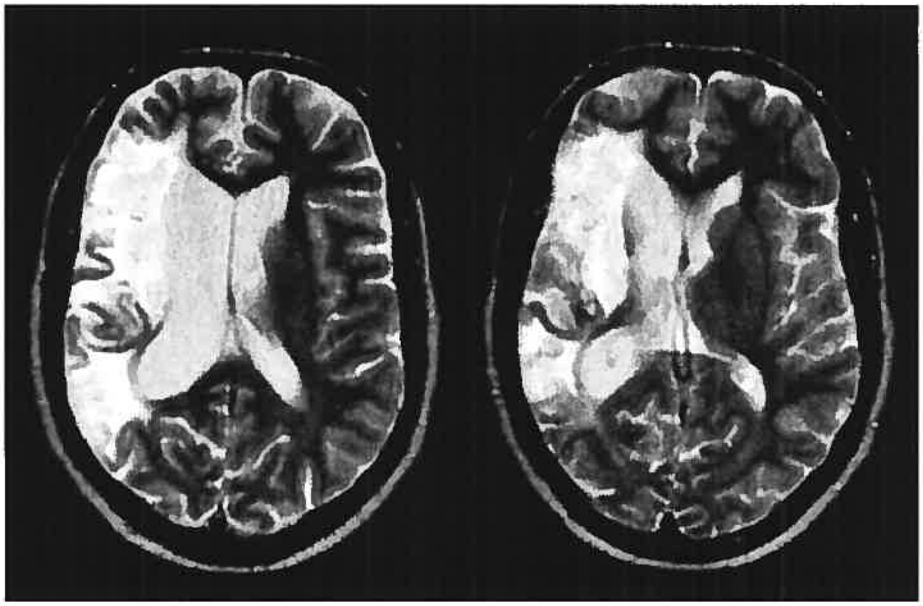
Results for unfamiliar songs (Experiment 2).

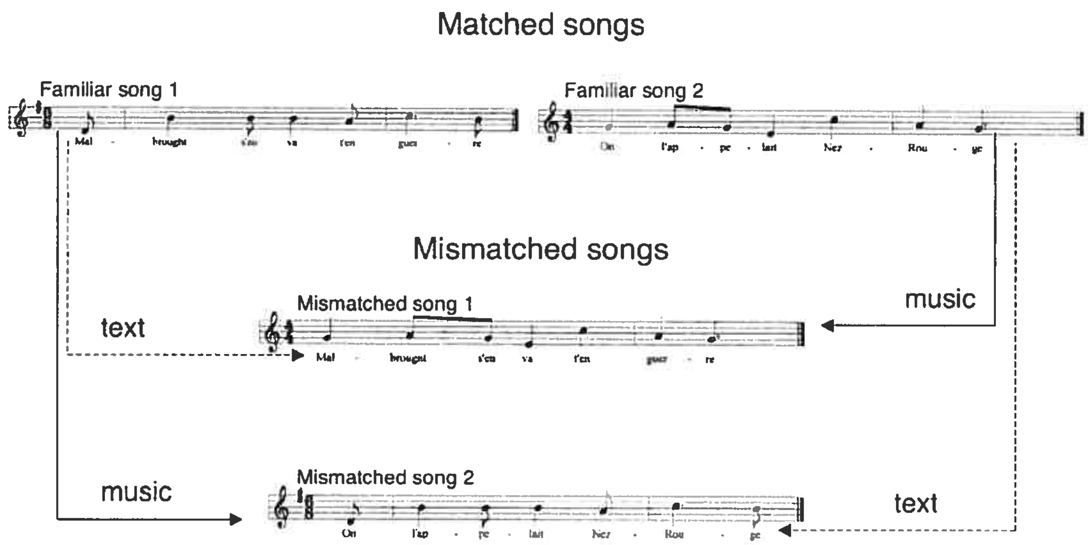
	Music			Language		
	CC Session 1	CC Session 2	Controls	CC Session 1	CC Session 2	Controls
Isolated	82%	90%	89.1% (77.8-96.8)	43.4%	68.2%	100%
Sung	79.5%	84.2%	92.2% (87.8-96.8)	50.9%	51.7%	99.8% (99.1-100)

Figure Captions

Figure 1a and 1b: MRI scan of CC, taken 66 months post-stroke, showing a right temporo-fronto-parietal lesion.

Figure 2: Example of how two mismatched songs were constructed from two matched songs in Experiment 1.




Matched songs
Familiar song 1
Familiar song 2
Mismatched songs
Mismatched song 1
text
music
Mismatched song 2
music
text

Article 4

Manuscrit à soumettre à la revue *Brain*

Making Non-fluent Aphasics Speak: Sing Along !

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RUNNING TITLE: MAKING NON-FLUENT APHASICS SING

KEYWORDS: aphasia, singing, songs, Melodic Intonation Therapy, music

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Abstract

A classic observation in neurology is that aphasics can sing words they cannot pronounce otherwise. To further assess this claim, we investigated the production of sung and spoken utterances in a group of eight brain-damaged patients suffering from a variety of speech disorders. In the first experiment, participants repeated or produced words and notes of familiar material from memory. Lyrics of familiar songs, as well as words of proverbs and prayers, were not better produced by singing than by speaking. Overall, note production was superior to word production in singing. In the other two experiments, the aphasic patients learned novel songs. There were not more lyrics produced by singing than by speaking in Experiment 3. In Experiment 4, participants sang or spoke along with the recording of the song line, at a normal and a slow speed. During this shadowing-like task, singing was better than speaking. Altogether the results suggest that singing can help memorize or articulate words only when patients can synchronize to the sung production, which constitutes a natural way to slow down production in the most severe cases of speech reduction.

Singing has been used with many populations suffering from a variety of neurological pathologies, including communication disorders (Cohen, 1994), as a therapy. Songs are able to stimulate communication in autism (Miller & Toca, 1979), to lessen stuttering (Andrews et al., 1982; Colcord & Adams, 1979; Stager et al., 2003), to improve fluency or verbal memory in Parkinson disease (Kempler & Van Lancker, 2002; Prickett & Moore, 1991), or to reveal learning capacities in amnesic patients (Baur et al., 2000; Haslam & Cook, 2002). Above all, singing is considered as an effective mean for non-fluent aphasics to produce words that they are not able to pronounce otherwise (Assal et al., 1977; Jacome, 1984; Keith & Aronson, 1975; Yamadori et al., 1977). Thus, music is of clinical interest with this population because it may help to recover speech after cerebral damage. Music may act at different stages of language processing. For instance, music may be effective at the motor stage by slowing down the output. Reduced speech rate may indeed improve intelligibility in dysarthric patients (for example, see Yorkston & Beukelman, 1981). Music may also contribute to word retrieval by providing cues and structural constrains, such as stress and syllable number. Therefore, it is important to determine who can be helped by music and why.

In fact, the use of music as a therapy for speech has given birth to the Melodic Intonation Therapy (MIT). This technique is used for language rehabilitation and works mainly when patients show slow, poorly articulated speech, and relatively good auditory comprehension. MIT is a "hierarchically structured rehabilitation program using high probability phrases and sentences which are intoned and tapped out in a syllable-by-syllable manner" (Naeser &

Helm-Estabrooks, 1985). The patient first repeats the "musical" sentence in unison with the therapist. The intonation is then gradually faded until the patient can produce the sentence by himself, eventually in a normal intonation (Sparks et al., 1974). The underlying idea of MIT was that musical tonal ability, a form of singing, is a right-hemisphere function. Thus, an early interpretation of successful recovery from aphasia with the MIT technique was that it facilitated the use of language areas of the right hemisphere, after damage to the language areas in the left hemisphere (Albert et al., 1973). A right hemisphere takeover during aphasia rehabilitation has been supported in a number of verbal tasks, such as word retrieval learning (Blasi et al., 2002), even when patients are not singing. However, a study by Belin et al. (1996) does not support this interpretation. They examined seven non-fluent aphasic patients who were successfully treated with MIT after spontaneous recovery had stopped. The authors used PET technology to measure relative cerebral blood flow during hearing and repetition of untrained words, and during repetition of MIT-loaded words. Repetition of untrained words activated right-hemisphere structures homotopic to those usually involved in language tasks, and deactivated left-hemisphere language-related zones. However, repetition of words trained with MIT elicited the opposite pattern of activation: right-hemisphere structures were deactivated while language-related left-hemisphere structures were active. Thus, activation of language areas homotopic to the damaged ones signed the persistence of aphasia rather than its recovery, suggesting that right-hemisphere activation would be a direct consequence of brain damage rather than an adaptive process.

When the effects of the melodic and rhythmic aspects of music were studied separately in a speech therapy inspired by the MIT, the rhythmic support seemed to be more crucial in improving speech (Boucher et al., 2001). In that study, two non-fluent aphasic patients followed four different treatments, one emphasizing intonation only (tone contour), two emphasizing rhythm (verbal pacing and hand-tapping) and one emphasizing both intonation and rhythm (melodic intonation). After each type of training, the patients were asked to repeat sentences. The treatments emphasizing rhythm led to better syllable repetition than treatments emphasizing intonation. The patient showing the most severe reduction in repetition benefited most from the rhythmic treatments, particularly in the initial stages of training. Hence, rhythmic exercises may be central in improving articulatory precision if used early in rehabilitation.

Another positive effect of musical rhythm is that singing slows down the rate of word production and thus, can improve intelligibility (Laughlin et al., 1979; Pilon et al., 1998). Pilon et al. (1998) used three different pacing methods with three dysarthric patients. During singing and metronome pacing, speech rate was 20% slower than baseline, while visually-guided pacing was 11% slower. A reverse correlation between intelligibility and speech rate was observed. The metronome pacing seemed the most efficient in increasing word intelligibility. Singing pacing did help the most affected patients while it disturbed the less affected patients. These results suggest that the mere presence of an external constraint facilitates speech when speech reduction is severe, probably by slowing down production. MIT success might also be explained by the same mechanism (Laughlin et al., 1979). Control over speech rate is often used to improve intelligibility with dysarthric patients (Hustad et al., 2003; Yorkston, Hammen, Beukelman & Traynor, 1990).

An additional reason why singing could improve speech is that words learned to music, as in songs, can become automatized. Automatic, or non-propositional, speech, which includes not only song lyrics but also prayers, proverbs, swearing, is usually preserved in non-fluent aphasia. Propositional, or generative, speech is much more vulnerable to brain damage (Blank et al., 2002; Ryding, et al., 1987; Speedie et al., 1993; Van Lancker-Sidtis et al., 2003). Moreover, in songs, words and melodies are learned together. If words and melody are associated in memory for songs, music may facilitate access to language. Studies of neurologically intact participants have shown that melody and lyrics are tightly associated in memory (Crowder et al., 1990; Peretz, Radeau et al., 2004; Serafine et al., 1984, 1986).

In sum, there are many different reasons that could explain why singing may improve language production. However, most reports of aphasics that can sing better than they can speak are descriptive. Moreover, there are many negative findings. For example, Luria (1972) reports that his famous patient Zasetsky "easily remembered the melodies of songs, if not the words. This meant that songs also seemed fragmented, consisting of a melodic part he could understand and a content that made no sense at all" (p.154). Several recent studies have also challenged the classic observation that sung productions are better than spoken productions of words. Cohen and Ford (1995) examined the production of 12 patients who became aphasic after a unilateral left-hemisphere vascular accident. Patients had to produce the words of the choruses of selected songs under three experimental conditions, that is, naturally spoken (without any support), spoken with a steady drumbeat accompaniment, and sung with the melody played on a keyboard. Content, error types, and number of intelligible words per minute were the dependent variables. It was found that the speech content and error types did not differ across conditions, but that word intelligibility was higher when utterances were spoken without any support, with respect to when sung or spoken with a drumbeat. However, several methodological aspects may account for these results. Hence, the type and severity of aphasia of the patients were not specified. It is unknown how impaired these patients were in their expressive speech abilities. The group data may not be representative of how each patient performed in the different conditions. Averaging of performance may create effects that do not reflect any of the individual performance, or may cancel out effects that would have been significant at the individual level (see Caramazza & McCloskey, 1988). In addition, as was suggested by the authors themselves, the word intelligibility index (i.e., the average number of intelligible words divided by the average duration of each condition) could have been compromised in the rhythm and melody conditions because judges had to listen to recorded speech with a drumbeat or electric keyboard in the background. Masking effects may contribute to the lower intelligibility in these conditions. Finally, performance on the melody of the songs was not assessed, so it is unknown if singing with the words was detrimental because patients had to produce both melody and words (a double task), or because words themselves were more difficult to produce while singing than while reciting with accompaniment. In addition, given that amusia is more often associated to aphasia than not, the presence of amusia, in some, or all of the patients, cannot be ruled out. The presence of amusia with aphasia may easily explain why the singing condition was the least successful.

However, single-case studies of aphasic patients who did not suffer from amusia have obtained convergent results (Hébert et al., 2003; Peretz, Gagnon et al., 2004). The two aphasics did not correctly produce more words when 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. Thus, the classic reports that non-fluent aphasic patients are able to sing, may simply reflect the dissociation between automatic speech (in singing) and propositional speech, such as in spontaneous speech. However, the two aphasic patients studied by Hébert and Peretz presented atypical forms of aphasia, that is, crossed aphasia and primary progressive aphasia, respectively. The goal of the present study was to generalize to more common forms of speech disorders.

To this aim, we conducted a multiple-case study with aphasic patients whose performance was compared when singing and speaking both familiar and novel utterances. A variety of speech deficits were considered to allow the exploration of a wide range of error types in production, with special attention to non-fluent aphasias that are known to respond best to Melodic Intonation Therapy (Sparks et al., 1974). In Experiment 1, we investigated patients' production of familiar material, such as traditional songs, prayers, proverbs and rhymes. If the automatic status of words in memory is a critical factor, then the aphasic patients should be rather fluent. However, this fluency should be observed for all familiar material, be it spoken or sung. The patients not only had to pronounce the lyrics of the songs, they also had to sing the words of prayers and proverbs on a familiar melody. If singing helps word production, then sung words should be more accurate than spoken words in producing both lyrics and well-known expressions.

In Experiments 2 and 3, patients learned novel songs, alone or in unison. If singing improves word production, repetition of sung words should be better than spoken words. Alternatively, if spoken and sung production is governed by the same processes, performance should not differ significantly whether words are sung or spoken. Unison production was performed at two different speeds in order to explore the role of speech rate on word intelligibility. Unison production should improve performance when compared to speaking or singing alone, because of the possibility to shadow the heard production. This should be particularly clear when rate of production is slowed down. "Choral speech" is known to improve speech fluency in stutterers (Saltuklaroglu et al., 2004).

In all three experiments, we predict that a sung presentation will lead to better word production than a spoken presentation, because music slows down tempo (Kilgour et al., 2000), hence allowing the listener to pay closer attention to the lyrics, and possesses constraints that help to structure recall (Poulin et al., 2004; Rubin, 1995; Wallace, 1994). We hoped that, by studying different forms of speech disorder, we could highlight the contribution of these different factors.

General Method

Participants

Eight non-fluent aphasics were recruited through an association of persons with aphasia (AQPA). A summary of the patients' characteristics is given in Table 1. All participants were right-handed, French-speaking, and suffered a left cerebral vascular accident (CVA) at least two years prior to this study. Patients were in a stable phase. No patient had pre-trauma history of neurological or psychiatric problems. CT scans examinations of 4 patients (because of the presence of metal) and MRI of three patients were obtained at the time of testing (summer 2002, except for JH for which we had the scan taken after his stroke in 1997). All participants had an infarct limited to the left side of the brain (see Figure 1). Informed consent was obtained from all patients and the study was approved by the Ethical Committee of the Montreal University Geriatric Institute.

Insert Table 1 around here

Insert Figure 1 around here

All patients had benefited from speech therapy after their stroke. Six had finished treatment at least two years before testing; one (LB) had stopped a few months prior to examination. One patient (JH) was still pursuing speech therapy because of continuous improvement in his communication abilities. At the time of testing, the patients were reevaluated by speech therapists, using the MT-86 (Nespoulous et al., 1992), a shortened version of the Token Test (De Renzi & Vignolo, 1962) and subtests of the French version of the Boston Diagnostic Aphasia Examination (BDAE; Mazaux & Orgogozo, 1981). On the basis of these tests, the patients were diagnosed as suffering from Broca's aphasia (JS, LB, RD), mixed aphasia with predominance of expressive deficits (RH, PP, CA, JH), and anomia (LD; see Table 1). The main diagnostic scores are presented in Table 2. As can be seen, the speech disorders were mainly expressive, affecting both oral and written language. Simple comprehension was well preserved. Individual scores were classified with respect to the severity of the impact of the disorder on conversation according to the criteria of the BDAE. Accordingly, the data are presented in Tables from the most to the less severe case (with LB, PP, JS being the most severe; next JH, CA; intermediate: RD; and moderate: RH, LD). In addition to the language problem, most cases (except JH and LD) suffered from dysarthria, an articulatory problem due to a weakness or an incoordination of speech muscles, and buccofacial apraxia, an inability to coordinate and carry out facial and lip movements. RH had a particularly severe dysarthria.

Insert Table 2 around here

In order to assess production of functional and emotional prosody, the patients were required to produce three neutral sentences with four different intonations: affirmation, question, joy and sadness. For comparison, three neurologically intact participants also produced the sentences with the same intonations. These renditions were randomly mixed and presented to five judges who had to guess and rate the intended intonation. The aphasic patients scored lower than controls for at least one intonation, especially joy. The fact that aphasics had pronunciation difficulties might have played a role.

Each participant was tested with a short neuropsychological battery of tests, including the digit span, the standard non-colored Raven's matrices (1996) and the Tower of London (Shallice, 1982; see Table 3). As expected, spans were particularly limited. Raven's matrices revealed good reasoning abilities in half of the participants. The other half was impaired. This is not too surprising since left-hemisphere lesions, especially in the frontal region, have been associated with difficulties in spatial reasoning (Langdon & Warrington, 2000). Disorders of executive functions, as revealed by planning difficulties at the Tower of London, were present in JS, and to a lesser degree in PP.

Insert Table 3 around here

Regarding musical abilities, it is worth mentioning that five aphasics (LB, PP, JS, CA, RH) participate in the choir activity organized by their association (AQPA), for two hours a week. The choir activity consists in singing along familiar tunes with the director. None of the participants had formal musical training. Their musical perception abilities were assessed with the Montreal Battery for Evaluation of Amusia (MBEA; Peretz et al., 2003). The scores are presented in Table 4. Five participants had normal scores, whereas two participants (PP and RD) were considered amusic, based on their composite score that lied two standard deviations below the mean of normal controls. PP's performance reflects a disorder in the temporal organization of music. RD' amusia is more severe; however, her residual pitch and temporal abilities revealed in the repetition of familiar melodies (see Experiment 1) seems sufficient to support singing.

General Procedure and Data Analysis

Patients participated in about four sessions of two-hour each to complete the testing. Sessions were adapted to the patients' capacities, with flexible durations, possibilities to get pauses and at-home testing. The testing sessions were recorded on a DAT Sony via a Shure 565SD microphone. All productions were saved in digital sound files after being transferred in the Cool Edit program (Syntrillium Software Corporation, 1996).

For text scoring, the experimenter and a university student in speech-language pathology transcribed all the words of each participant. Words were considered correct or incorrect, irrespectively of their pitch and duration when sung. Moreover, words incorrectly produced, but that would have been guessed correctly out of their context, gave half a point. Words were chosen over syllables because number of syllables sometimes differs across conditions; mute vowels are often sung but not pronounced. Contractions, such as articles or short words that were not produced on a note, were considered as part of the word to which they were attached. A point was given for every word correctly produced, in the correct order. Every word counts. Omissions and substitutions gave no point. The number of correct words was the number of words both judges gave a point to. The words on which they disagreed were discarded. The score corresponded to the number of words both judges gave a point or half a point to, divided by the total number of words both judges agreed on and multiplied by 100, for each song. A total of 4957, 1835 and 4960 words were computed respectively in Experiment 1, 2 and 3, with inter-raters agreements of 92%, 96% and 88%.

For musical notes scoring, two musically trained judges transcribed the musical productions and gave a score for each performance. Pitch intervals and directions were analyzed irrespectively of verbal content. Rhythmic pattern was not considered, mainly because of the numerous pauses or hesitations patients made during word production. The number of correct notes was the number of notes both judges gave a point to. When there was a disagreement, the note was discarded from the total of notes in the excerpt. The musical notes score corresponded to the total of correct pitches for each production divided by the total number of possible notes minus the notes both raters disagreed upon for these productions, multiplied by 100. A total of 7717, 1410 and 3398 musical notes were computed in Experiment 1, 2 and 3, with inter-raters agreements of 95%, 85% and 79%, respectively.

Because of the limited number of patients and the variability between subjects, non-parametric tests were used to analyze the data. Unless otherwise indicated, an alpha level of .05 was used for all statistical tests.

EXPERIMENT 1

Production of Familiar Material

Method

Patients were presented with two types of material. The first material consisted of fourteen familiar songs selected from a repertoire of children and traditional songs in Quebec (Peretz et al., 1995). Song excerpts were, on average, 5 words (range: 3 to 7) and 9 notes (range: 6 to 11) long. The second material was composed of two well-known prayers ("Our Father" and "Holly Mary"), six proverbs (e.g. "All roads lead to Rome") and one nursery rhyme (e.g. "Eenie, meenie, minie, mo"). We will refer to this material as "verbatim speech". The sentences were, on average, 7 words (6 to 10) and 8.5 notes (7 to 12) long.

Patients had to perform two tasks on these materials: a repetition task and a recall from memory task. In the repetition task, the experimenter gave the first line and the participant had to repeat it in the same mode. That is, when spoken, the words had to be recited; when sung, the words had to be sung. To that aim, the verbatim speech lines were sung to a familiar melody. Eight familiar songs that matched the number of syllables in the line were used. The second task implied recall from memory: the titles were presented to participants, who had to produce as much as they knew of the song, prayer or rhyme. For the proverbs, the only possible task was to give the beginning of the expression (e.g., An apple a day...) and ask for completion (... keeps the doctor away). The completion of verbatim speech was always performed before the repetition task. Otherwise, order of presentation was counter-balanced across participants. At the end, spontaneous production and repetition of the songs' melodies on the syllable /la/ were assessed in one single block, in a counter-balanced order of tasks. Throughout the experiment, live presentation was used, hence enabling the use of visual as well as auditory cues. Patients could also ask the experimenter to repeat the title or the line if necessary.

Results

Individual scores, corresponding to the percentage of correct words or notes produced, obtained for the different songs and for the different verbatim expressions were averaged for each participant and for each task (repetition and recall; see Table 5) and compared with Wilcoxon tests. Because there was no difference between the three materials of verbatim speech (completion of proverbs from memory did not differ from the recall of prayers and rhyme, $\underline{Z} = 1.26$, $\underline{p} > .05$), these were pooled together in the analyses. The results will be presented for songs first and then for verbatim speech. For these two types of automatic productions, two conditions (isolated, combined) and two tasks (repetition, recall) will be compared for words and for musical notes. The isolated condition refers to the production of words only or musical notes only, while the combined condition refers to the sung production of both words and notes. Error types in word production was also assessed and compared between the sung and the spoken conditions.

Songs

As can be seen in Table 5, the percentage of words correctly produced was not higher in singing than in speaking, in both repetition, $\underline{Z} = 0.34$, n.s., and recall, $\underline{Z} = 0.56$, n.s. This held true for each patient when considering song excerpts as the random variable (all $\underline{p} > .05$, by Wilcoxon Tests). Only one patient (LB) produced more words from memory in singing than in speaking, $\underline{Z} = 1.96$, $\underline{p} = .05$. Nevertheless, there was a significant correlation between participants' scores in singing and speaking, in repetition, $\underline{r}\ (8) = .99$, $\underline{p} < .001$, as well as in recall, $\underline{r}\ (8) = .89$, $\underline{p} < .01$, suggesting that common mechanisms are involved in the two conditions.

Yet, patients seem to recall more words from songs while singing. To assess this, the number of words attempted in production from the title was calculated, irrespectively of their accuracy. It confirmed that participants would go further in the song when singing, $\underline{M} = 166$ words, $\underline{SE} = 18.8$, than when reciting the lyrics, $\underline{M} = 119$ words, $\underline{SE} = 14.6$, with $\underline{Z} = 2.38$, $\underline{p} < 0.05$.

Insert Table 5 around here

The most frequent errors committed by the patients were phonemic paraphasias (39%), that is, nonwords which share phonemes with the target word. The other errors were omissions (31%), neologisms (12%), and semantic paraphasias (11%), that is, real words semantically related to the target word. There were very few lexical paraphasias (i.e., real words with no semantic relation with the target word; 6%). In repetition, the error types were similar in singing and speaking (all p values > .05), except for the phonemic errors which were more frequent in singing (45%) than in speaking (33%), $Z = 1.96$, $p < 0.05$. This was true for all but one participant (RH) who suffers from a severe dysarthric problem. When committing these phonemic paraphasias, patients respected the number of syllables in the word in 92% of the cases, thus preserving the rhythmic structure of the word in the line, both when singing and when pronouncing the words. Moreover, vowels were correctly produced in 84% (range: 38%-100%) of the cases while the correct consonants were only preserved in 29% (range: 0%-59%).

For all patients but LD, production of musical notes was much easier than words. This was confirmed statistically in singing songs (with words combined with musical notes), in both repetition, $Z = 1.82$, $p = 0.07$, and recall, $Z = 2.10$, $p < 0.05$ (see Table 5). A similar trend is apparent when participants were producing musical notes or words alone, although it did not reach significance. This dissociation between word and note production is corroborated by the fact that none of the correlations computed between the word and the note scores reached significance (all p > .05). The problem of LD to sing the notes seems related to a production deficiency rather than a perceptual or memory difficulty. As can be seen in Table 4, LD was not impaired on the MBEA.

In general, word performance was higher in repetition than in recall, both in singing, $Z = 2.52$, $p < 0.05$, and in reciting, $Z = 2.38$, $p < 0.05$, although the three patients with the most severe form of aphasia (LB, PP, JS) had very low scores in both tasks. Similarly, the percentage of musical notes correctly produced was higher in repetition than in recall, both when produced alone, $Z = 2.52$, $p < 0.05$, and with words, $Z = 2.20$, $p < 0.05$. While the combined production of words and notes did not improve word production as compared to the isolated production of each component, it did help note production, in recall, $\underline{Z} = 2.03$, $\underline{p} < 0.05$. The same tendency was present in repetition, but failed to reach significance, $\underline{Z} = 1.61$, $\underline{p} > 0.05$. Thus, the combined production was beneficial to musical note production, but not to word production. This is probably due to the fact that the patients continued singing even when words were not correct.

Verbatim Speech

Comparing the sung and spoken production of popular expressions is interesting because speech therapists often use functional sentences sung to a melody to improve speech (e.g. “See you tomorrow”, Keith & Aronson, 1975). However, the present results suggest that this strategy is not very effective (see Table 6). No effect of condition was obtained in repetition of verbatim speech; the percentage of correctly repeated words was not higher in singing than in speaking, $\underline{Z} = 0.98$, n.s. An analysis considering the different expressions for each patient yielded a positive effect of singing in only one participant (LB), with $\underline{Z} = 2.06$, $\underline{p} < .05$, the same patient who benefited from singing for songs. Here, she was unable to articulate a single word while reciting. However, two other patients (JS, RD) exhibited the reverse pattern, with spoken repetitions being better than sung repetitions, $\underline{Z} = 2.03$ and 2.20, $\underline{p} < .05$. JS was unable to repeat the expressions in singing. The other participants had similar performance in the two modalities (all $\underline{p}$ values > .05).

Here, omission was the most frequent error (53%). Phonemic paraphasias (21%) were again more frequent than semantic paraphasias (3%). Comparisons of the proportions of each error type in the sung and the spoken conditions revealed only one significant difference for neologisms (e.g.: tantan for claire). These errors were more frequent in singing (14.3%) than in speaking (10.6%; $Z = 1.99$, $p < 0.05$). When making phonemic errors, patients respected the number of syllables in the word in 89% of the cases when singing and 94% of the cases when pronouncing the words, thus preserving the rhythmic structure of the word in the line. Moreover, vowels were correctly produced in 82% (range: 43%-96%) of the phonemic paraphasias while the correct consonants were only preserved in 34% (0-75%) of the cases.

Finally, we compared performance obtained with the two different materials. Indeed, songs and verbatim speech are comparable in terms of their automatic status in memory, but one is musical and the other is verbal. When possible, performance obtained with verbatim speech was compared to performance obtained in the same conditions with familiar songs. Song lyrics were always better produced than verbatim speech, in sung repetition, $Z = 2.52$, $p < 0.05$, in spoken repetition, $Z = 2.03$, $p < 0.05$, and there was a trend in that direction in spoken recall, $Z = 1.68$, $p = 0.09$. The musical note scores were also lower when the melody was repeated with the verbatim speech than when repeated with its original lyrics, $Z = 2.52$, $p < 0.05$, suggesting the presence of interference in learning a new association between words and melody, although both are familiar.

Insert Table 6 around here

Discussion

Singing did not improve word production compared to speaking. Even in songs, where lyrics are usually sung, there was no advantage of singing the words over speaking them. This was also true for verbatim speech, such as proverbs and prayers, which were not better repeated when sung on a familiar melody than when spoken. However, singing helps memory retrieval. The patients were able to retrieve more of the song lyrics from memory when singing than when speaking, even though accuracy was similar in both expression modes.

Musical production was generally higher than speech, hence supporting the observation that speech and music disorders can dissociate after brain damage. Except for one patient (LD), access to the melody was more accurate when it was sung with its original lyrics than with unrelated but familiar sentences (i.e. verbatim speech). Moreover, musical notes were also best recalled when sung together with the associated lyrics than when sung on /la/. In contrast, word production was as accurate in singing as in speaking. This pattern of results suggests that the association between lyrics and melody of a song is asymmetrical: the melody would be more dependent on word retrieval than vice versa.

Finally, words in songs are more easily produced than words from prayers or proverbs. Different factors may account for this advantage. Songs may be more familiar, by being more often practiced or heard, than prayers or proverbs. This difference in frequency of occurrence would make songs more accessible in memory than verbatim speech. Songs are also stored in memory in a dual code, that is, in a speech and a musical code (Samson & Zatorre, 1990). The melody might act as an additional cue that facilitates the word retrieval compared to prayers or proverbs. Thus, the automatic status of the material does not seem to account entirely for the advantage of song production over spontaneous speech in aphasic patients. Sung material is easier to produce for aphasics, as far as familiar songs are concerned.

EXPERIMENT 2

Novel Song Learning

Familiar songs may have a special status in memory, because words have been integrated to the melody through repeated exposure and practice. When learning novel songs, the sung version bears no advantage over the spoken version since they are both heard together for the first time. If singing does indeed facilitate word production in non-fluent aphasics, sung words should be better produced than spoken words when learning novel songs. The goal of the present experiment was to test this prediction. Furthermore, the putative influence of music at encoding words rather than in producing them was also examined.

Material

Unfamiliar songs were chosen from the repertoire of Claude Gauthier, a popular French-Canadian folk-singer, author and composer. Four songs with few repetitions of words or melodic lines were selected. The four songs used in the present study had a theme, most often referring to love. Thus, the words were predictable (e.g., amour/love, fleurs/flowers, coeur/heart), but different enough across songs to prevent confusions (see Table 7 for an example). The 115 words used in the songs had a mean frequency of 2650 per million, including function words, based on a French lexical database (New et al., 2001): 76% were highly frequent, with a frequency of usage higher than 50 per million. Only 10% of the words had a low frequency, corresponding to less than 15 per million. The musical notes (nine per line on average) outnumbered words (six per line on average), t (31) = 11.21, SE = .22, $p < .001$, because 26% of the words were disyllabic and 6% trisyllabic. The songs had a stable structure and were judged to be as "good" as hits from the same singer (see Racette & Peretz, submitted).

From the four songs, eight four-line excerpts were included for the learning task (see Table 7). On average, an excerpt contained 25 words (range: 21-27) and 34 notes (range: 28-38). An additional four-line excerpt from an unfamiliar choir song (mean of 5 words and 9 notes per line) by Joseph Steuerlein (1974) served as a training song.

The four songs and the training song were produced a capella (without instrumental accompaniment) by a female singer, who learned the songs beforehand. The same singer also sung each song on /la/ and pronounced the lyrics with a natural intonation. The best performance of each song in each version was recorded on a DAT Sony via a Shure 565SD microphone, and then transferred into a computer and edited with the Cool Edit program (Syntrillium Software Corporation, 1996). The three versions of the same song served to create two types of stimuli, the sung songs and the "divided" songs. The latter were created by coupling each spoken line with its corresponding melody sung on /la/, in order to give the spoken presentation of words the same musical context than the sung presentation of words. In these divided songs, the intensity of the melody had to be decreased by 32%, on average, in order to make the spoken version intelligible. The intelligibility of songs' lyrics was equivalent in the sung and the "divided" songs.

As expected, the length of the original spoken version was about half of the length of the sung version (M = 2.48 and 4.95 s per line, respectively, t (31) =

13.44, $p < .001$). Because the divided condition combined both the spoken and the "sung on /la/" versions (M = 4.92 s per line), divided and sung presentations had equivalent lengths (respectively, M = 4.94 and 4.95 s per line). In the divided condition, the shorter spoken line was placed in the middle of the sung melody, so that it was preceded and followed by equivalent durations of the melody.

Procedure

The practice song was learned before each condition. It served to determine the number of attempts that each participant needed in order to achieve his/her best repetition of a line. Patients had always the same number of attempts to repeat a line throughout the experiment. The number of trials varied between two for JH, RD, RH, LD, three for LB, JS, CA, and four for PP. Then, the patients heard the whole song to be learned in order to familiarize themselves with the song. Then, (s)he had to repeat (as many times as determined previously) one line at a time, following the procedure shown in Table 7. Each time a line was added, the patient had to recall them from the beginning, until all four lines had been presented, repeated, and recalled.

Insert Table 7 and 8 around here

Presentation of the song lines was either sung or spoken (with the melody in the background, referred to as the "divided" presentation). Repetition was sung, spoken or sung on /la/ (see Table 8). In the sung-sung condition, the patient listened to the sung version of the lyrics and sung them back. In the sung-spoken condition, the patient listened to the sung version of the lines and repeated only the lyrics, by pronouncing them in a natural way. In the divided-spoken condition, the participant listened to the divided version of the lines and repeated again only the lyrics. In the last condition, divided-hummed, the participant listened to the divided version and repeated only the melody, on the syllable /la/. The patients learned one song in each condition, for a total of four different songs. The order of presentation of the conditions which implied repetition of lyrics (sung-sung, sung-spoken, divided-spoken) was counter-balanced across participants. The divided-hummed condition was done last.

Data Scoring

The best repetition performance and the production of the whole song (lines 1 to 4) were analyzed for words and notes. The best repetition corresponded to the best word repetition performance, not the best note repetition. The first attempt was the best in 50% of the lines for the word conditions and 56 % of the lines for the hummed condition. Recall scores corresponded to the proportion of words correctly produced for all four lines.

Results

As in Experiment 1, word accuracy and error types will be analyzed and compared in singing and in speaking. This analysis will be followed by the results obtained on musical note. Finally, the scores obtained here for novel songs will be compared to those obtained with familiar songs in Experiment 1.

As can be seen in Table 9 and 10, there was a large variability in the scores obtained in each condition. Despite this important variability, none of the patient obtained a higher score in the sung-sung condition. Singing did not help word repetition. The comparison of the three conditions involving words (sung-sung, sung-spoken, divided-spoken; Table 9) did not reveal difference, χ^2 (2) = 1.23, p >

0.05 (by Friedman Test). Similar effects were obtained with recall scores (χ^2 (2) = 2.74, p > 0.05; see table 9).

Insert Table 9 around here

The rate of word production was calculated in order to examine if singing slowed down aphasic's speech relatively to speaking. The rate corresponded to the total duration of word articulation (independently of accuracy) divided by the number of syllables produced. In repetition, it was found that sung syllables were about 13% longer than spoken syllables. Thus, sung syllables (mean: 0.57 s; range: 0.41-0.80 s) were slower than the spoken syllables (mean: 0.49 s; range: 0.28-0.68 s), but not significantly so, with $Z = 1.69$, $p = .09$.

The types of word errors were similar across the three conditions in repetition and there was no effect of condition (all p values > .05). Omissions were the most common type of error (40%). As for familiar songs, phonemic paraphasias were slightly more frequent in the sung condition (34% versus 17% and 20% for the sung-spoken and the divided-spoken conditions respectively). Compared to university students, who only made omissions and substitutions (Racette & Peretz, submitted), aphasic patients made more omissions and slightly less substitutions (semantic and lexical paraphasias). Hence, phonemic paraphasias were specific to aphasic patients; they preserved the syllabic structure of the word in 85% of the cases, the vowels in 80% and the consonants in only 37%. Finally, patients made an equivalent number of errors (13%) in singing (by reciting) and in speaking (by singing), except PP who always repeated the melody instead of the words, even in the divided-spoken condition.

Insert Table 10 around here

As can be seen in Table 10, the patients did not reproduce more musical notes when singing with words (sung-sung condition) than when singing on /la/ (divided-hummed condition), $Z = 1.61$, $p > 0.05$ and $Z = 0$, n.s., for repetition and recall, respectively. The scores for notes repetition were actually higher without than with words for six patients. The proportions of correctly reproduced words and musical notes were also compared and did not yield any significant difference in the sung-sung condition, with $Z = 0$ and 0.67, both n.s., in repetition and recall, respectively. The same was true when notes and words were produced in isolation after the divided presentation, $Z = 0.14$ and 1.19, both n.s., in repetition and recall, respectively. There was no correlation between word and note scores (all $p <.05$). As expected, recall scores were always inferior to repetition scores, in each condition and for each component (all p values $< .05$).

Familiar versus unfamiliar songs.

In order to assess the advantage given by the automatic status of the familiar material, repetition of familiar songs' lines was compared to repetition of unfamiliar songs' lines. The scores for familiar songs were always higher than the scores for unfamiliar songs, both for word repetition in singing, $Z = 2.38$, $p < .05$, and in speaking, $Z = 1.89$, $p = .06$, and for note repetition, with or without words, $Z = 2.52$, $p < .05$.

Discussion

Music did not improve fluency or verbal memory for novel song lyrics. Moreover, the aphasic patients made the same type of errors when singing and when speaking, suggesting that the speech output whether sung or spoken was controlled by the same mechanisms. Music had no effect at presentation either.

Hearing a text sung (in the sung-spoken condition) did not lead to a better word production than hearing the text spoken (in the divided-spoken condition). Thus, the results obtained here with unfamiliar songs parallel those found with familiar songs in Experiment 1.

Unlike Experiment 1, aphasics did not reproduce more notes than words. In fact, note reproduction was more difficult here. In our prior study with neurologically intact participants, we have observed that students performed much better on the verbal than the musical component of new songs (Racette & Peretz, submitted). Here, in aphasics, the difference between words and notes production would be reduced. For instance, most aphasics could still repeat more notes than words, since they were strongly limited verbally.

EXPERIMENT 3

Unison Repetition and Recall

In this experiment, we examined another strategy that is often used in speech therapy, particularly the MIT, in which aphasics first sing words in unison with the therapist before trying to sing them alone. We examined here how the patients benefit from singing and speaking in unison. This idea came from the observation of the patients in the previous experiments and in the choir. When producing speech, most of the patients tried to "tune" their output with somebody else. Thus, this last experiment consisted in a shadowing-like task or "choral speech", whereby the participants had to shadow what they listened to. However, as in Experiment 2, they first listened to each line before shadowing. Furthermore, in order to assess the role of speed on word articulation, two rates of presentation were used: the original speed (i.e. the one used in Experiment 2) and a much slower one.

Method

Only the sung-sung and the divided-spoken conditions were used here at the same speed as used in Experiment 2. These versions were slowed down by 50%, using the Cool Edit program (Syntrillium Software Corporation, 2000). This reduction of speed was chosen because it preserved the naturalness of the voice. Otherwise, the same learning procedure as used in Experiment 2 was followed here except that, during repetition and recall, the patients produced the words while listening to the target song lines. The sung-sung and divided-spoken conditions were administered in the same order as used in Experiment 2 for a given patient. Two songs were learned in each condition: one song at the original speed first and then at the slow speed, and vice versa for the other song. Thus, the same song was learned twice, in the original and in the slow speed. The speed was counter-balanced across conditions. A total of four songs were learned, different from the ones learned in Experiment 2, two while singing and two while speaking.

Insert Figure 2 around here

Participants wear a headset (Alset Lansing) to listen to the songs that were played via a portable Panasonic CD player (see Figure 2). What was playing on the CD player was recorded "on-line" on a DAT Sony and time-locked to the patient's production that was recorded on another channel of the DAT recorder. That way, the judges could listen to the two channels, the participants' production and what (s)he was hearing, for scoring purpose. The judges could also listen to the participants' production alone, with no interference from the other channel. The best repetition was analyzed, and it corresponded to the first attempt for 40% of the lines.

Results and Comments

In this experiment, two conditions (sung-sung, divided-spoken) and two speeds (original, slow) could be compared, in repetition and in recall from the beginning of the song. Word scores will first be analyzed, along with the types of error committed in repetition. Then, musical note scores will be examined. Afterwards, a possible order effect will be analyzed. Finally, the effect of shadowing will be assessed. The results are presented in Tables 11 and 12.

For the first time, singing was found to improve word production. There was indeed an effect of condition on word repetition when scores were averaged over the two speeds, $Z = 2.10$, $p < .05$. There was a trend in the same direction when performance was examined at the slow speed, with $Z = 1.89$, $p = .06$, and at the original speed, with and $Z = 1.82$, $p = .07$. Similarly, recall scores in the sung-sung condition were superior to the recall scores in the divided-spoken condition, with $Z = 2.03$, $p < .05$ at the slow speed, and $Z = 1.68$, $p = .09$ at the original speed. Thus, more intelligible words were produced in singing than in speaking. When song lines were used instead of participants in the analysis, half of the patients (LB, PP, JS, CA) showed the effect of condition both in repetition and in recall. These patients were actually the ones with the most severe aphasia. Among the other half, with less severe expressive reduction, participants had no effect of condition, except RD in repetition and LD in recall.

The effect of speed was also present in the expected direction. In repetition, the effect of speed was significant in speaking, $\underline{Z} = 2.24$, $\underline{p} < .05$, but not in singing, $\underline{Z} = 1.35$, $\underline{p} > .05$. Speaking at a slow speed generally improved word production compared to a normal speed. This difference was present in all participants except LD but reached statistical significance in only two patients (LB, RD). In recall, more correct words were produced when singing slowly than normally, $\underline{Z} = 2.37$, $\underline{p} < .05$, and the same trend was present in speaking, $\underline{Z} = 1.68$, $\underline{p} = .09$. Using line recall scores, three patients (JS, RD, RH) had an effect of speed in singing only, and one patient (PP) in speaking only. Most patients had small score differences between the two speeds (see Table 11).

Insert Table 11 around here

When syllable duration (in seconds) was measured during patients' repetition, it was found that sung syllables were about 42% longer than spoken syllables at the slow speed and 35% longer at the original speed. These proportions are much larger than the 13% found in Experiment 2, when participants were not shadowing ($\underline{Z} = 2.20$, $\underline{p} < .05$). The rate of speech is here significantly slower in singing than in speaking, with $\underline{Z} = 2.52$ and 2.38, $\underline{p} < .05$, for the slow and the original speed, respectively. Moreover, the patients with the most reduced speech were the ones who seemed to benefit more from singing. Thus, the effect of singing could be confounded with an effect of speed. In order to assess the relationship between speed of articulation and word intelligibility, the individual rate of articulation obtained in each condition was plotted as a function of the word score. This plot is presented in Figure 3. As can be seen, there seems to be a trade-off between speed and accuracy in the most severe cases. To assess this statistically, the individual scores obtained for each line were analyzed by multiple regression, using syllable duration and condition (singing=1, speaking=0) as factors. The regression was a rather poor fit (R^2 adjusted = 10%), and the overall relationship was just close to significance, $F(2, 249) = 15.27$, $p = .06$. Both the effect of speed, $t(251) = 4.60$, $p < .001$, and the effect of condition, $t(251) = 5.17$, $p < .001$, were significant. When the data of each patient were analyzed separately (with about 32 observations per patient), the four patients with the lowest scores and the most severe aphasias (LB, PP, JS, CA) exhibited a significant relationship. The language disorders of these patients (severe speech reduction) actually make them the best candidates to the MIT.

Insert Figure 3 around here

Error types as a proportion of total errors while singing or while speaking were compared. Again, phonemic errors were more frequent while singing than while speaking, $Z = 2.10$, $p < .05$. No other comparison was significant, the error types being similar in both conditions and speeds.

Compared to the proportion of intelligible words repeated, the proportion of musical notes correctly repeated was not superior, in both the slow and the original speeds (all p values > .05), for the group. However, repetition scores for LB, PP, JS and RH were higher for notes than for words at both speeds. Similarly, in recall, there was a trend for more notes than words to be correctly recalled, both at the original speed, $Z = 1.86$, $p = .06$, and at the slow speed, $Z = 1.68$, $p = .09$. The individual scores obtained in musical note recall were indeed larger than the scores obtained in word recall when singing, in all patients except JH, RD and LD. Patients with the most severe reduction of speech are thus consistently better in note production while the patients with better speech abilities do not show such a musical advantage. There was no difference between the original and the slow speed versions in repeating musical notes, $\underline{Z} = 1.40$, $\underline{p} > .05$, but recall at the original speed was inferior to recall at the slow speed, $\underline{Z} = 2.24$, $\underline{p} < .05$.

In each condition, participants learned the songs twice, once at the slow speed and once at the original speed. In order to assess if there was an effect of order of presentation, we compared the results obtained when the song was learned for the first time to the scores obtained when the song was learned the second time, for each condition and speed. The only significant result obtained was an order effect in the sung-sung condition, with the first performance being worse than the second, $\underline{Z} = 2.10$, $\underline{p} <.05$.

Insert Table 12 around here

Effects of shadowing.

Before shadowing all the lines from the beginning, participants were invited to recall alone, from memory. These scores are presented in Table 11. The results obtained with these scores yielded an effect of condition at both the original and slow speed, $\underline{Z} = 1.99$, $\underline{p} < .05$ and $\underline{Z} = 1.86$, $\underline{p} = 0.06$, respectively, favoring speaking over singing. Thus, the direction of this effect is opposite to the one obtained with shadowing, the scores obtained in the divided-spoken condition being superior to the ones obtained in the sung-sung condition. Thus, spoken recall appears better than sung recall when shadowing is not allowed. The condition effect obtained while shadowing is thus closely related to the possibility to synchronize with what is heard and to use the auditory presentation as an aid for memory.

In order to further assess the role of unison on performance, we compared the proportion of intelligible words repeated in Experiment 2 and 3 at the original speed. In repetition, four patients (LB, PP, JH, CA) in the sung-sung condition and three (LB, PP, JH) in the divided-spoken condition had better word repetition scores while shadowing. All but one participant (JH) had their worse musical note score in singing alone. However, when group results were analyzed, no effect of shadowing emerged in singing, $\underline{Z} = 1.35$, $\underline{p} > .05$, nor in speaking, $\underline{Z} = 0.28$, $\underline{p} > .05$. Repetition of musical notes was better in unison than alone, $\underline{Z} = 2.38$, $\underline{p} < .05$.

Discussion

Singing along is better than speaking in unison. This effect might well be ascribed to speed. Indeed, there was a trade-off between speed of articulation and word intelligibility in the most severe cases of aphasia. Moreover, the shadowing task succeeded in slowing down substantially the rate of articulation of the patients.

The benefit of shadowing was more salient during recall than in simple repetition. Thus, singing or reciting words in unison might benefit memory more than pronunciation. This conclusion is also consistent with the fact that shadowing also helped note production. The benefit would not be related to speech but to general processes such as memory and attention.

GENERAL DISCUSSION

The main finding from the present study is that singing does not help aphasics to improve their speech. Singing only helps patients suffering from a severe speech reduction to produce more intelligible words when they can synchronize their output with someone else (Experiment 3). Singing along only improves word recall and not word repetition. Therefore, singing along does not improve speech per se but rather improves attention and memory. This may explain why speech shadowing is generally hard for aphasic patients (Lackner & Shattuck-Hufnagel, 1982; Woods, 1987). Speech shadowing has been used previously in stutterers in order to improve speech fluency (Kalinowski et al., 2000; Saltuklaroglu et al., 2004; Stager & Ludlow, 1993). This technique has sometimes been called choral speech and has used auditory cues (the participant hears what s/he has to produce) as well as visual cues (the participant sees someone speaking the words s/he has to produce). Explanations for the effect of choral speech on fluency have included reduction in communicative responsibility, inducement of novel patterns of vocalization, external timing mechanisms and innate gestural mirroring (Kalinowski & Saltuklaroglu, 2003). The present results suggest that non-speech factors are at work. Singing in unison is indeed easier than speaking along because it is more regular, more natural and, above all, slower. Singing in unison allowed patients with the most severe aphasias to slow down significantly their rate of speech. This slowing down effect appears sufficient to explain the advantage of singing in unison over speaking.

The positive effect of speed reduction points to a possible motor role of music in facilitating speech. An increase in processing demands, such as an increase in speaking rate, may cause a breakdown in speech production of non-fluent aphasic patients (Baum, 1993). These patients might be limited in the maximum speed at which articulation can be produced (Baum, 1992). Acceleration of the speech rate would have a greater impact on pauses and consonant production than on vowels duration, which cannot be decreased beyond a certain limit (Baum, 1993). This was indeed the case in our patients. A reduction in speed would allow aphasic patients more time for phonetic implementation, a motor limitation often central to their speech deficit (Baum, 1993). However, in our study, phonemic errors were more frequent in singing, even if rate of articulation was slowed down. Therefore, the effect of speed observed here might be best explained in terms of non-speech factors. It remains to determine if these factors are related to musical activities that emphasize temporal more than pitch performance aspects (Boucher et al., 2001). Our study suggests that synchronization, which is time-related, supports best aphasics' oral performance, be it sung or spoken.

In our tasks, repetition was always easier than recall, probably because the latter makes additional processing demands from memory. This is also consistent with the results obtained with the shadowing task that led to a much better recall performance than when recall was tested without auditory assistance. Memory load may also account for the classic finding that non-propositional speech, which characterizes familiar song recall (Experiment 1), is generally more preserved than propositional speech in aphasia (Lum & Ellis, 1999). Non-propositional speech recruits additional retrieval mechanisms (Blank et al., 2002). Therefore, non-propositional (automatic) speech might be spared when propositional (generative) speech is affected. This is true for repetition versus recall, for shadowing versus production alone. Shadowing is indeed a task that relies more on automatic than generative processes.

As observed here in Experiment 1 and 2 and as reported previously (Hébert et al., 2003; Peretz, Gagnon et al., 2004), when patients were producing words alone, without shadowing, singing did not facilitate word articulation. This applied to unfamiliar songs learning but also, surprisingly, to familiar songs that are normally sung and not spoken. This result replicates the findings obtained in single cases suffering from atypical aphasia (Hébert et al., 2003; Peretz, Gagnon et al., 2004) and extends these conclusions to a variety of speech disorders caused by a left-hemisphere lesion. The similarity in the proportion of intelligible words and in the types of error committed suggests again that there is a unique code for words, either sung or spoken.

Producing words with music did not improve the quantity and the quality of words produced, but hearing words with music did not improve repetition and recall either. This lack of influence of music at encoding, and thereby the negligible role played by speed at presentation, is consistent with prior work focusing on language. Indeed, it has been shown that non-fluent aphasics do not usually benefit from a slower presentation to improve comprehension (Blumstein et al., 1985; Brookshire & Nicholas, 1984).

Although we found limited support for the idea that singing helps aphasics to recover speech, we think that music therapies should still be considered when treating aphasic patients. From our results, we can predict that MIT is useful in the initial stages, when patients with severe speech limitations sing in unison with the therapist. What happens in the subsequent stages was no assessed in this study, and the long-term benefits of singing along are still unknown. Moreover, there are additional benefits that may be provided by music in therapy. Because aphasic patients do not necessarily suffer from a music disorder, producing musical notes alone is still a good way for them to produce vocal sounds. Most of our patients had profiles of aphasia without amusia (Brust, 2001; Warren et al., 2003). Moreover, even the ones who had a concomitant musical impairment in perception, memory or production, did not show a different pattern than the patients without amusia in singing. Hence, most aphasic patients seem to enjoy singing, which motivates them to participate in sessions and keeps their spirit high. Moreover, singing has sometimes been chosen as a therapy because it is different from speaking and therefore, it allows practicing a wider range of voicing and articulation (Cohen, 1994).

References

Albert ML, Sparks RW, Helm NA. Melodic intonation therapy for aphasia. Arch Neurol 1973; 29: 130-1.

Andrews G, Howie PM, Dosza M, Guitar BE. Stuttering: speech pattern characteristics under fluency-inducing conditions. J Speech Hear Res 1982; 25: 208-216.

Assal G, Buttet J, Javet RC. Aptitudes musicales chez les aphasiques. Rev Med Suisse Romande 1977; 97: 5-12.

Baum SR. The influence of word length on syllable duration in aphasia: Acoustic analyses. Aphasiology 1992; 6: 501-513.

Baum SR. An acoustic analysis of rate of speech effects on vowel production in aphasia. Brain Lang 1993; 44: 414-30.

Baur B, Uttner I, Limberger J, Fels G, Mai N. Music memory provides access to verbal knowledge in a patient with global amnesia. Neurocase 2000; 6: 415-421.

Belin P, Van Eeckhout P, Zilbovicius M, Remy P, Francois C, Guillaume S, et al. Recovery from non-fluent aphasia after melodic intonation therapy: a PET study. Neurology 1996; 47: 1504-11.

Blank SC, Scott SK, Murphy K, Warburton E, Wise RJS. Speech production: Wernicke, Broca and beyond. Brain 2002; 125: 1829-1838.

Blasi V, Young AC, Tansy AP, Petersen SE, Snyder AZ, Corbetta M. Word retrieval learning modulates right frontal cortex in patients with left frontal damage. Neuron 2002; 36: 159-170.

Blumstein SE, Katz B, Goodglass H, Shrier R, Dworetsky B. The effects of slowed speech on auditory comprehension in aphasia. Brain Lang 1985; 24: 246-65.

Boucher V, Garcia LJ, FLeurant J, Paradis J. Variable efficacy of rhythm and tone in melody-based interventions : Implications for the assumption of a right-hemisphere facilitation in non-fluent aphasia. Aphasiology 2001; 15: 131-149.

Brookshire RH, Nicholas LE. Consistency of effects of slow rate and pauses on aphasic listeners' comprehension of spoken sentences. J Speech Hear Res 1984; 27: 323-8.

Brust JCM. Music and the neurologist : A historical perspective. In: Zatorre RJ and Peretz I, editors. The biological foundations of music. New York: The New York Academy of Sciences, 2001.

Caramazza A, McCloskey M. The case for single-patient studies. Cognitive_Neuropsychology 1988; 5: 517-27.

Cohen NS. The use of superimposed rhythm to decrease the rate of speech in a brain-damaged adolescent. J Music Ther 1988; 25: 85-93.

Cohen NS. Speech and song: Implications for therapy. Music Therapy Perspectives 1994; 12: 8-14.

Cohen NS, Ford J. The effects of musical cues on the nonpurposive speech of persons with aphasia. J Music Ther 1995; 32: 46-57.

Colcord RD, Adams MR. Voicing duration and vocal SPL changes associated with stuttering reduction during singing. J Speech Lang Hear Res 1979; 22: 468-79.

Crowder RG, Serafine ML, Repp B. Physical interaction and association by contiguity in memory for the words and melodies of songs. Mem Cognit 1990; 18: 469-76.

De Renzi E, Vignolo L. The token test: A sensitive test to detect receptive disturbances in aphasics. Brain 1962; 85: 665-678.

Haslam C, Cook M. Striking a chord with amnesic patients: evidence that song facilitates memory. Neurocase 2002; 8: 453-65.

Hébert S, Racette A, Gagnon L, Peretz I. Revisiting the dissociation between singing and speaking in expressive aphasia. Brain 2003; 126: 1838-50.

Hustad KC, Jones T, Dailey S. Implementing speech supplementation strategies: effects on intelligibility and speech rate of individuals with chronic severe dysarthria. J Speech Lang Hear Res 2003; 46: 462-74.

Jacome DE. Aphasia with elation, hypermusia, musicophilia and compulsive whistling. J Neurol Neurosurg Psychiatry 1984; 47: 308-10.

Kalinowski J, Saltuklaroglu T. Choral speech: the amelioration of stuttering via imitation and the mirror neuronal system. Neurosci Biobehav Rev 2003; 27: 339-47.

Kalinowski J, Stuart A, Rastatter MP, Snyder G, Dayalu V. Inducement of fluent speech in persons who stutter via visual choral speech. Neurosci Lett 2000; 281: 198-200.

Keith R, Aronson A. Singing as therapy for apraxia of speech and aphasia: Report of a case. Brain Lang 1975; 2: 482-488.

Kempler D, Van Lancker D. Effect of speech task on intelligibility in dysarthria: A case study of Parkinson's disease. Brain Lang 2002; 80: 449-464.

Kilgour AR, Jakobson LS, Cuddy LL. Music training and rate of presentation as mediators of text and song recall. Mem Cognit 2000; 28: 700-10.

Lackner JR, Shattuck-Hufnagel SR. Alterations in speech shadowing ability after cerebral injury in man. Neuropsychologia 1982; 20: 709-14.

Langdon D, Warrington EK. The role of the left hemisphere in verbal and spatial reasoning tasks. Cortex 2000; 36: 691-702.

Laughlin SA, Naeser MA, Gordon WP. Effects of three syllable durations using the melodic intonation therapy technique. J Speech Hear Res 1979; 22: 311-320.

Lum C, Ellis AW. Why do some aphasics show an advantage on some tests of nonpropositional (automatic) speech? Brain Lang 1999; 70: 95-118.

Luria AR. The man with a shattered world. Cambridge: Harvard University Press, 1972.

Mavlov L. Amusia due to rhythm agnosia in a musician with left hemisphere damage: a non-auditory supramodal defect. Cortex 1980; 16: 331-8.

Mazaux, JM, Orgogozo, JM. HDAE-F. Boston Diagnostic Aphasia Examination. Issy les Moulineaux : Éditions Scientifiques et Psychologiques, 1981.

Miller SB, Toca JM. Adapted melodic intonation therapy: a case study of an experimental language program for an autistic child. J Clin Psychiatry 1979; 40: 201-203.

Naeser MA, Helm-Estabrooks N. CT scan localization and response to melodic intonation therapy with non-fluent aphasia cases. Cortex 1985; 21: 203-223.

Nespoulous JL, Lecours AR, Lafond D. MT-86-Protocole Montréal-Toulouse d'examen linguistique de l'aphasie. Isberges: Ortho-Edition, 1986.

New B, Pallier C, Ferrand L, Matos R. Une base de données lexicales du français contemporain sur internet: LEXIQUE. Année Psychol 2001; 101: 447-462.

Peretz I, Babai M, Lussier I, Hebert S, Gagnon L. Corpus d'extraits musicaux : indices relatifs à la familiarité, à l'âge d'acquisition et aux évocations verbales. Can J Exp Psychol 1995; 49: 211-39.

Peretz I, Champod AS, Hyde K. Varieties of musical disorders. The Montreal Battery of Evaluation of Amusia. Ann N Y Acad Sci 2003; 999: 58-75.

Peretz I, Gagnon L, Hébert S, Macoir J. Singing in the brain: Insights from cognitive neuropsychology. Music Perception 2004; 21: 373-390.

Peretz I, Radeau M, Arguin M. Two-way interactions between music and language: evidence from priming recognition of tune and lyrics in familiar songs. Mem Cognit 2004; 32: 142-52.

Pilon MA, McIntosh KW, Thaut MH. Auditory vs visual speech timing cues as external rate control to enhance verbal intelligibility in mixed spastic-ataxic dysarthric speakers: A pilot study. Brain Inj 1998; 12: 793-803.

Poulin-Charronnat B, Bigand E, Madurell F, Peereman R. Musical structure modulates semantic priming in vocal music. Cognition 2005; 94: B67-78.

Prickett C, Moore R. The use of music to aid memory of Alzheimer's patients. J Music Ther 1991; 28: 101-110.

Racette & Peretz (submitted). Learning lyrics: To sing or not to sing? Mem Cognit.

Raven, JC. Standard Progressive Matrices: Sets A, B, C, D & E. Oxford, UK: Oxford Psychologists Press, 1996.

Rubin DC. Memory in oral traditions. New York: Oxford University Press, 1995.

Ryding E, Bradvik B, Ingvar DH. Changes of regional cerebral blood flow measured simultaneously in the right and left hemisphere during automatic speech and humming. Brain 1987; 110 (Pt 5): 1345-58.

Saltuklaroglu T, Kalinowski J, Guntupalli VK. Towards a common neural substrate in the immediate and effective inhibition of stuttering. Int J Neurosci 2004; 114: 435-50.

Samson S, Zatorre RJ. Learning and retention of melodic and verbal information after unilateral temporal lobectomy. Neuropsychologia 1992; 30: 815-26.

Samson S, Zatorre R. Recognition memory for text and melody of songs after unilateral temporal lobe lesion : Evidence for dual encoding. J Exp Psychol Learn Mem Cogn 1991; 17: 193-804.

Serafine ML, Crowder RG, Repp BH. Integration of melody and text in memory for songs. Cognition 1984; 16: 285-303.

Serafine ML, Davidson RJ, Crowder RG, Repp BH. On the nature of melody. Text integration in memory for songs. J Mem Lang 1986; 25: 123-135.

Shallice, T. Specific impairments of planning. Philos Trans R Soc Lond 1982; 298: 199-209.

Sparks R, Helm N, Albert M. Aphasia rehabilitation resulting from melodic intonation therapy. Cortex 1974; 10: 303-16.

Speedie LJ, Wertman E, Ta'ir J, Heilman KM. Disruption of automatic speech following a right basal ganglia lesion. Neurology 1993; 43: 1768-1774.

Stager SV, Jeffries KJ, Braun AR. Common features of fluency-evoking conditions studied in stuttering subjects and controls: an H(2)15O PET study. J Fluency Disord 2003; 28: 319-335.

Stager SV, Ludlow CL. Speech production changes under fluency-evoking conditions in nonstuttering speakers. J Speech Hear Res 1993; 36: 245-53.

Van Lancker-Sidtis D. When novel sentences spoken or heard for the first time in the history of the universe are not enough: toward a dual-process model of language. Int J Lang Commun Disord 2004; 39: 1-44.

Wallace WT. Memory for music : Effect of melody on recall of text. J Exp Psychol Learn Mem Cogn 1994; 20: 1471-1485.

Warren JD, Warren JE, Fox NC, Warrington EK. Nothing to say, something to sing: primary progressive dynamic aphasia. Neurocase 2003; 9: 140-55.

Woods BT. Impaired speech shadowing after early lesions of either hemisphere. Neuropsychologia 1987; 25: 519-25.

Yamadori A, Osumi Y, Masuhara S, Okubo M. Preservation of singing in Broca's aphasia. J Neurol Neurosurg Psychiatry 1977; 40: 221-4.

Yorkston KM, Beukelman DR. Communication efficiency of dysarthric speakers as measured by sentence intelligibility and speaking rate. J Speech Hear Disord 1981; 46: 296-301.

Yorkston KM, Hammen VL, Beukelman DR, Traynor CD. The effect of rate control on the intelligibility and naturalness of dysarthric speech. J Speech Hear Disord 1990; 55: 550-60.

Authors Notes

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Table 1. *Screening Data for All Patients*

	Sex	Age	Education	Years since last infarct	Number of infarcts	Diagnosis	Etiology
LB	F	56	10	5	1	Severe Broca's aphasia Severe dysarthria	Left sylvian CVA
PP	M	45	11	6	2	Severe mixed aphasia	Left sylvian CVA
JS	M	55	18	20	1	Severe Broca's aphasia	Left fronto-parietal aneurysm Thalamic lacuna cerebri
JH	M	62	20	5	1	Moderate to severe mixed aphasia Predominantly expressive deficit	Left sylvian CVA
CA	F	36	14	13	1	Moderate to severe mixed aphasia Predominantly expressive deficit	Aneurysm of the anterior and mid left cerebral artery
RD	F	54	9	19	1	Moderate Broca's aphasia	Left sylvian CVA
RH	M	67	7	9	2	Atypical Broca's aphasia Severe dysarthria No aggramatism	Left sylvian CVA
LD	F	38	15	19	1	Mild to moderate anomia	Left sylvian CVA

Table 2.

Linguistic Assessment

	LB	PP	JS	JH
MT-86 aphasia battery				
Expression				
Naming	0/6	11/31	26/31	17/31
Verbal fluency	3	0	13	15
Automatized speech				
Digits 1 to 10	n	n	n	n
Days of the week	n-	d	n	n
Months of the year		d	n	n
Words of familiar song	d	d	d	n
Melody of familiar song	n	n	n	n
Repetition				
Syllables	5/20	19/20	3/20	20/20
Words and nonwords	10/30	22/30	17/30	30/30
Sentences	0/3	0/3	0/3	2/3
Auditory comprehension				
Words	9/9	9/9	9/9	9/9
Simple sentences	6/6	6/6	5/ 6	6/6
Complex sentences	24/32	25/32	23/32	28/32
Body-part identification	8/8	7/8	8/8	8/8
Object manipulation	5/8	5/8	5/8	6/8
Reading comprehension	5/9	14/20	16/23	15/23
Dictation		3/7	4/9	0
Token Test	16/36	10.5/36	13.5/27	22/36

n = normal performance; n- = with help; d = deficit

Table 2. *(continued)*

	CA	RD	RH	LD
MT-86 aphasia battery				
Expression				
Naming	30/31	31/31	28/31	28/31
Verbal fluency	35	38	32	36
Automatized speech				
Digits 1 to 10	n	n	n	slow
Days of the week	n	n	n	slow
Months of the year	n	n	n	slow
Words of familiar song	n-	n	n	n-
Melody of familiar song	n-	n	n	n-
Repetition				
Syllables	16/20	18/20	11/20	20/20
Words and nonwords	28/30	27/30	21/30	30/30
Sentences	1/3	1/3	0/3	1/3
Auditory comprehension				
Words	8/9	9/9		9/9
Simple sentences	6/6	6/ 6	6/6	6/6
Complex sentences	24/32	24/32	32/32	28/32
Body-part identification	8/8	8/8	8/8	9/9
Object manipulation	5/8	7/8	8/8	7.5/8
Reading comprehension	17/23	18/23	23/23	13/13
Dictation	2/4	1/6	23/35	N
Token Test	16.5/28	28.5/36	29/36	26.5/36

n = normal performance; n- = with help; d = deficit

Table 3.

Neuropsychological Assessment

	Digit span	Raven Matrices (percentile)	Tower of London Mean number of movements (Mean total time in sec)*
LB	3	48/60 (41 p.)	8.3 (26.3)
PP	2	52/60 (50 p.)	9.75 (30.75)
JS	3	27/60 (< 5 p.)	10.7 (100.7)
JH	4	35/60 (10 p.)	5.2 (25.7)
CA	3	42/50 (11 p.)	6.4 (33.8)
RD	4	41/60 (12 p.)	7 (38.5)
RH	4	39/60 (25 p.)	5.4 (21.7)
LD	3	52/60 (50 p.)	5.1 (18)

* The standard norms for the Tower of London are M = 5.75 SE = 1.49 for the mean number of movements and M = 24.67 SE = 24.5 for the mean total time.

Table 4.

Patients' Score on the Musical Battery of Evaluation of Amusia. The maximal score on each test is 30 (chance is 15).

	Scale	Contour	Interval	Rhythm	Meter	Memory	Composite score
LB	29	25	26	26	26	25	26
PP	27	25	24	21*	18*	16*	22*
JS	26	24	24	26	27	20*	25
JH	24	29	21	30	22	25	25
CA	24	26	22	28	26	25	25
RD	19*	21*	18*	22*	20	15*	19*
RH	30	28	29	27	20	24	26
LD	27	24	25	30	23	26	26
Cut-off score	22	22	21	23	20	22	23

* below cut-off

Table 5.

Percentages of Correct Word and Note Production for Familiar Songs

		Repetition		Recall	
		Combined	Isolated	Combined	Isolated
LB	Words	54	56	50	34
	Notes	90	98	90	85
PP	Words	34	38	24	16
	Notes	83	81	43	41
JS	Words	13	10	6	10
	Notes	98	91	80	24
JH	Words	93	93	73	71
	Notes	100	98	94	95
CA	Words	91	83	66	69
	Notes	93	85	70	72
RD	Words	89	90	65	72
	Notes	88	82	88	67
RH	Words	85	89	66	72
	Notes	96	92	83	64
LD	Words	84	78	49	77
	Notes	74	63	31	18
Mean	Words	67.9	67.1	49.9	52.6
	Notes	90.3	86.3	72.4	58.3

Table 6.

Percentages of Word and Note Production for Verbatim Speech

		Repetition		Recall
		Combined	Isolated	Isolated
LB	Words	28	0	7
	Notes	77		
PP	Words	18	9	0
	Notes	75		
JS	Words	0	11	28
	Notes	22		
JH	Words	59	78	48
	Notes	77		
CA	Words	50	72	83
	Notes	38		
RD	Words	50	84	71
	Notes	27		
RH	Words	84	82	48
	Notes	84		
LD	Words	76	84	51
	Notes	55		
Mean	Words	45.6	52.5	39.8
	Notes	56.9		

Table 7.

Illustration of the Adaptive Learning Procedure with Two Trials

Lyrics presented	Lyrics repeated	Lyrics to be recalled
1 Dans cette petite boîte vide 1 Dans cette petite boîte vide 	1 Dans cette petite boîte vide 1 Dans cette petite boîte vide	
2 Avec un ruban de velours 2 Avec un ruban de velours 	2 Avec un ruban de velours 2 Avec un ruban de velours	1 Dans cette petite boîte vide 2 Avec un ruban de velours
3 Il y a tout mon cœur et mes rides 3 Il y a tout mon cœur et mes rides 	3 Il y a tout mon cœur et mes rides 3 Il y a tout mon cœur et mes rides	1 Dans cette petite boîte vide 2 Avec un ruban de velours 3 Il y a tout mon cœur et mes rides
4 Mon sourire et tout mon amour 4 Mon sourire et tout mon amour 	4 Mon sourire et tout mon amour 4 Mon sourire et tout mon amour	1 Dans cette petite boîte vide 2 Avec un ruban de velours 3 Il y a tout mon cœur et mes rides 4 Mon sourire et tout mon amour

Table 8.

Modes of Presentation and Production in Each Condition of Experiment 2

Presentation	Repetition/recall
Sung	Sung
Sung	Spoken
Spoken – Sung on /la/	Spoken
Spoken – Sung on /la/	Sung on /la/

Table 9.

Percentages of Words Produced in Experiment 2

Participant		Word production: Sung-sung	Sung-spoken	Spoken-spoken
LB	Repetition	9	31	14
	Recall	8	0	0
PP	Repetition	5	0	0
	Recall	0	0	0
JS	Repetition	9	10	11
	Recall	4	8	10
JH	Repetition	54	51	50
	Recall	13	9	14
CA	Repetition	26	49	56
	Recall	0	9	4
RD	Repetition	69	50	70
	Recall	25	4	44
RH	Repetition	78	83	88
	Recall	21	26	24
LD	Repetition	85	70	83
	Recall	36	29	63
Mean	Repetition	41.9	43.0	46.5
	Recall	13.4	10.6	19.9

Table 10.

Percentages of Notes Produced in Experiment 2

Participant		Note production: Sung-sung	Note production: Sung on /la/ - sung on /la/
LB	Repetition	28	89
	Recall	6	58
PP	Repetition	37	33
	Recall	0	4
JS	Repetition	43	69
	Recall	0	0
JH	Repetition	60	67
	Recall	56	11
CA	Repetition	30	34
	Recall	0	0
RD	Repetition	17	50
	Recall	11	39
RH	Repetition	70	48
	Recall	21	16
LD	Repetition	15	23
	Recall	28	0
Mean	Repetition	37.5	51.6
	Recall	15.3	16.0

Table 11.

Percentages of Words Produced in Experiment 3 (Shadowing-like Task)

		Words			
		Original speed		Slow speed	
		Sung-sung	Divided-spoken	Sung-sung	Divided-spoken
LB	Repetition	62	26	57	44
	Recall	41	22	60	30
	Alone	13	10	10	8
PP	Repetition	41	16	55	25
	Recall	38	7	38	18
	Alone	0	0	0	0
JS	Repetition	7	0	29	1
	Recall	13	1	22	0
	Alone	3	3	3	2
JH	Repetition	83	76	81	84
	Recall	64	55	70	74
	Alone	26	38	12	38
CA	Repetition	75	52	75	59
	Recall	52	36	59	35
	Alone	10	14	4	21
RD	Repetition	68	30	65	58
	Recall	34	27	41	44
	Alone	18	27	2	36
RH	Repetition	59	79	76	84
	Recall	22	37	39	35
	Alone	25	32	23	40
LD	Repetition	85	88	93	85
	Recall	67	54	78	70
	Alone	0	61	0	21
Mean	Repetition	60.0	46.3	66.4	55.0
	Recall	41.4	31.4	50.9	38.3

Table 12.

Percentages of Notes Produced in Experiment 3 (Shadowing-like Task)

		Notes	
		Original speed	Slow speed
LB	Repetition	81	76
	Recall	80	87
PP	Repetition	86	100
	Recall	89	100
JS	Repetition	62	69
	Recall	56	65
JH	Repetition	56	66
	Recall	55	52
CA	Repetition	76	80
	Recall	64	66
RD	Repetition	49	40
	Recall	34	45
RH	Repetition	83	89
	Recall	37	55
LD	Repetition	79	87
	Recall	61	77
Mean	Repetition	71.5	75.9
	Recall	59.5	68.4

Figure Captions

Figure 1. Axial CT and MRI of eight patients with vascular infarction drew on anatomical plates.

Except for one patient where part of the left anterior cerebral territory is also involved, the ischemic lesions involve the middle cerebral artery distribution, mainly the opercular frontal and temporal territories. According to the convention in imaging, the right side of the brain is on the left of the photograph.

Figure 2. Setting for Experiment 3.

Figure 3. Word accuracy according to syllable duration for each patient in Experiment 3.

LB

PP

JS

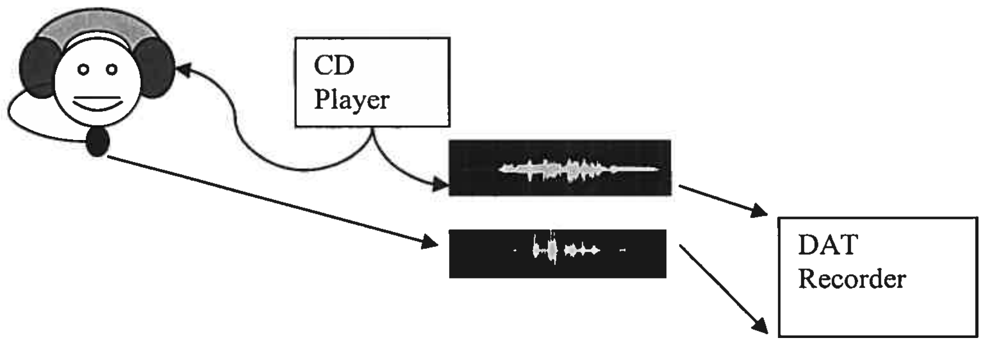
JH

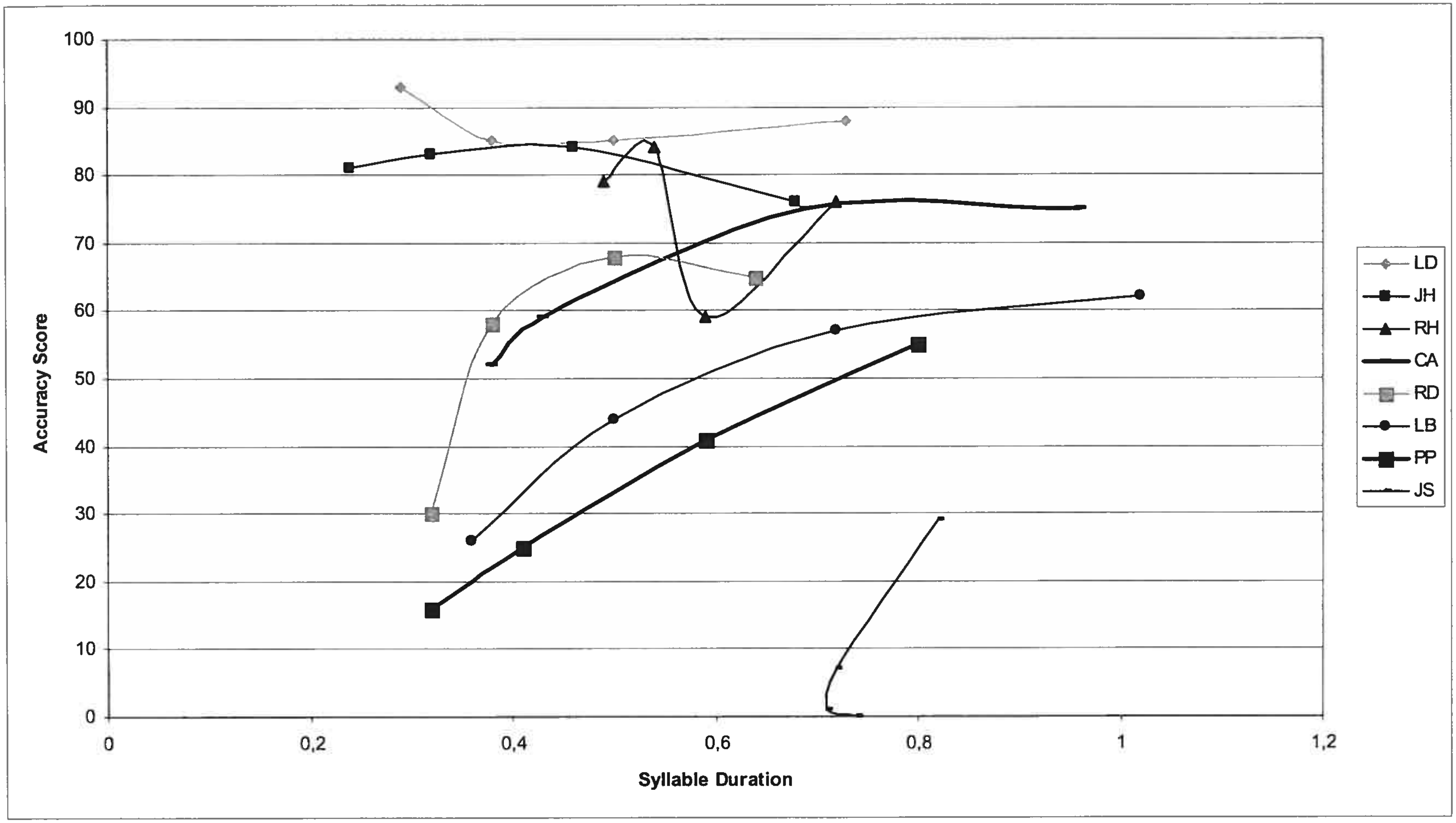
CA

RD

RH

LD


CD
Player
DAT
Recorder


Accuracy Score
100
90
80
70
60
50
40
30
20
10
0
0
0,2
0,4
0,6
0,8
1
1,2
Syllable Duration
LD
JH
RH
CA
RD
LB
PP
JS

CONCLUSION

Article 5

En révision pour un livre en l'honneur de Luigi Vignolo

Édité par Peter Mariën et Jubin Abutalebi

Should we make aphasic patients sing?

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Singing is a highly enjoyable experience. It also 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 one 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 aphasic patients, and ordinary people in general, are rarely studied. There are two main reasons for this limited attention: cultural bias and measurement problems. First, the widely spread cultural bias is that singing is poor in the general population. Most people are believed to be unable to carry a tune. This point of view was probably shared by Luigi Vignolo who has always been interested by the nonverbal abilities of aphasic patients, as indicates his pioneering work on the recognition of nonverbal sounds (Vignolo, 1969, 1982) and his more recent interest in music processing (Vignolo et al., , 2003). Had Luigi Vignolo trusted his own musical abilities, he would have tried to make his patients sing. Indeed, there is a growing body of research showing that ordinary adults are able to sing. Nonmusicians are found to be 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.

The second reason for the neglect of singing abilities relates to the problem of measurement. It is always easier to collect data in the form of responses from a limited set (e.g., « same-different » classification) than it is from multidimensional performance. This concern for precision and simplicity in measurement has led to a concentration of research on musical receptive abilities in the ordinary listener. This is also true in neurological settings. It is unfortunate because production data are much richer. The analysis can rely on auditory transcription into notation, or to auditory-only analysis by expert musicians. For example, Bergeson & Trehub (2002), in their study of maternal singing, had the mothers' productions judged by two experts, who matched the initial or tonic pitch of the song to a keyboard note, to the nearest quarter tone, and used a metronome to match the average tempo of the renditions. Although constrained by the "ear" of the listeners, to a certain extent, these analyzes usually yield very good interrater reliability (95% and over in this case). And more importantly, the examination of production allows discoveries that could not be obtained by simple perception studies. Bergeson and Trehub (2002) found out that mothers, when singing to their baby, have little variability in a given song's starting pitch over one-week time, whereas they have high variability in their speech starting pitch for a given sentence. This finding suggests that mothers with no special music training have almost an "absolute" mental representation of a song. Although the baby's productions are stable only around the age of five, this remarkably stable rendition of songs by the mother over time may serve different needs in the mother-baby relationship, such as the soothing of the baby, the promotion of social bonds, and, perhaps, the focusing of attention to particular words of the songs.

Some bits of information about the singing of aphasic patients come from neurologists who have commented on, or reported (qualitatively), the singing of their patients. For example, Luria's famous patient, Zasetsky, was damaged on the left side of the brain. He could easily remember the melodies of songs, though not their words (Luria, 1973). However, many reported that severely aphasic patients who, having recovered none or few of their speech abilities, are still able to sing previously learned songs with well-articulated and linguistically intelligible words. Such patients, with a very restricted output with respect to spontaneous speech, seem to be able to recover word articulation with the support of melody. These observations come mainly from patients who became aphasic after brain damage due to vascular cerebral accident (Assal, Buttet, & Javet, 1977; Jacome, 1984; Yamadori & al., 1977). For instance, Keith and Aronson (1975) reported the case of a brain-damaged woman who could not express herself by speaking, but could do so by singing phrases such as "How are you" or "I want coffee". With the exception of Assal and collaborators (1977), whose patients were amateur or professional musicians, other reports concern patients with no particular music training. Thus, this ability to sing with words seems not restricted to people who had previous music training, but seems to rather reflect a general trait of cerebral organization. The traditional interpretation of this long-standing observation has been that singing familiar songs would depend on right-hemisphere functions, whereas propositional (generative) speech would depend on left-hemisphere functions. Damage to the left hemisphere, therefore, would leave intact the patients' ability to sing previously learned songs, whereas damage to the right hemisphere would impair "automatic" speech and familiar song singing.

The question of why aphasic patients would be able to sing while not being able to speak is of clinical and theoretical interest. On a clinical level, the observation of such patients is at the origin of the Melodic Intonation Therapy (MIT), a technique that has been considered as the most promising avenue for aphasia rehabilitation by the American Neurology Association (Therapeutics and Technology Assessment subcommittee of the American Academy of Neurology, 1994). MIT does not use the singing of familiar songs *per se* as a form of therapy. Rather, it uses intonation patterns that exaggerate the normal melodic content of phrases that gradually vary in complexity as the patient makes progress, with the underlying idea being that musical tonal ability, a form of singing, is a right-hemisphere function. An early interpretation of successful recovery from aphasia with the MIT technique was that it facilitated the use of language areas of the right hemisphere, after damage to the language areas in the left hemisphere (Albert, Sparks, & Helm, 1973). Subsequently, this interpretation was revised and it was suggested that the increased use of melodic aspects of speech increases the role of the right hemisphere in inter-hemispheric control of language (Sparks, Helm, & Albert, 1974). However, a study by Belin, Van Eeckhout, Zilbovicius, and al. (1996) does not support either one of these interpretations. They examined seven nonfluent aphasic patients who were successfully treated with MIT after a period of time where spontaneous recovery had stopped. They used PET technology to measure relative cerebral blood flow during hearing and repetition of untrained words, and during repetition of MIT-loaded words. Repetition of untrained words activated right-hemisphere structures homotopic to those usually involved in language tasks, and deactivated left-hemisphere language-related zones. However, repetition of words trained with MIT elicited the opposite pattern of activation: that is, right-hemisphere structures were deactivated while language-related left-hemisphere structures were active. Thus, activation of language areas homotopic to the damaged ones signed the persistence of aphasia rather than its recovery, suggesting that right-hemisphere activation would be a direct consequence of brain damage rather than an adaptive process. While the study supports the potential value of MIT in functional rehabilitation, this rehabilitation was here associated with a shift from right-hemisphere activation to a reactivation of left-hemisphere structures. This finding is consistent with some other recent data showing reactivation of left hemisphere structures in successful recovery of language (e.g., Heiss Kessler, Thiel, Ghaemi, & Karbe, 1999), and contrasts with the classical view about the right-hemisphere structures taking over left-hemisphere structures in aphasia recovery (e.g., Papanicolaou, Bartlett, Moore, & Deutsch, 1988; Sparks, Helm, & Albert, 1974). Certainly, from a clinical point of view, understanding if, and why, singing would be an important tool for rehabilitation, is of significant importance.

On a theoretical level, there is a growing body of evidence in favor of the autonomy of speech and music. The terms aphasia and amusia used in neurology, designate acquired impairment of language and music processing, respectively. These disorders occur jointly more often than not (Marin & Perry, 1999), probably because a natural brain lesion or disease is most likely to globally affect cognitive functions such as language and music. However, several clinical cases of patients afflicted with aphasia but without amusia have been described. Often, the patients were professional musicians. The most notable case is probably the one of 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, four years later. According to Shostakovitch, one of his peers, Shebalin's music was undistinguishable from what he had composed before his illness (Luria, Tsvetkova, & Futer, 1965). Other similar cases have been reported in the literature (Assal, 1973; Jacome, 1984; Basso & Capitani, 1985; Signoret, van Eeckhout, Poncet, & Castaigne, 1987; Tzortzis, Goldblum, Dang, Forette, & Boller, 2000). Aphasia without amusia is, however, not limited to musicians, as illustrated in Zasetsky who was not musically trained (Luria, 1973).

Reverse cases, although less common, have also been reported regarding the presence of amusia without aphasia. These are more recent cases, and often concern patients who did not have any particular music training. The case of IR, for example, is outstanding since despite being able to write poems, IR could not recognize her national anthem or the song Happy Birthday (Peretz, Belleville, & Fontaine, 1997). Other such cases have been described (e.g., Ayotte, Peretz, Rousseau, Bard, & Bojanowski, 2000; Griffiths et al., 1997; Hébert & Peretz, 2001; Peretz Kolinsky, Tramo, & al., 1994; Piccirilli, Sciarma, & Luzzi, 2000 Steinke, Cuddy, & Jakobson, 2000 Wilson & Pressing, 1999). On the whole, such double dissociations suggest independence between language and music processing.

Songs, however, probably the most ancient form of art, uniting music and language within the same frame, represent an interesting challenge. Songs are a unique combination of text and music. The latter are separable in many ways, for they rely on separate codes and are even often composed by different persons. Yet, music and text are linked and are most often, if not always, heard and played in a combined form, from an early age.

In normal (healthy) listeners, studies have shown that recognition of songs is always better when text and tune are put in their original combination, with respect to when they are heard in a combination other than original. This effect had been taken as evidence that text and melody of a given song are integrated in memory, that is, represented by a single code rather than two (Serafine & al., 1984, 1986). Further studies, however, have suggested a strong association, rather than integration, between text and melody (Crowder et al., 1990; Hébert & Peretz, 2001; Peretz, Radeau & Arguin, 2004). This strong association in memory would enable music to facilitate word recall. Yet, although music is used as a mnemotechnic to learn and remember text by students and children (Dickson & Grant, 2003), it is still unclear by what mechanisms it would be effective. One hypothesis is that production of words is slowed down when singing compared to when speaking. Kilgour, Jakobson & Cuddy (2000) have shown that a sung text is better recalled than a spoken text as long as the sung text is slower than the spoken one. When the sung text is compressed to be as brief as the (same) spoken text, the advantage in recall disappears. Speed would thus be a crucial variable in the effect of music on word recall. Repetition and simplicity of a melody have also been brought forth as explanations for the better word recall of songs over spoken text: It has been documented that the advantage of having a simple melody repeated throughout a song is reversed when the music is complex and changing (Wallace, 1994). Overall, experimental studies that have addressed the question of the effect of music on verbal recall have mainly examined whether or not presenting music along with text enhances word recall. Only one study has examined whether the response produced (sung or spoken) yielded an advantage in word recall when considering the way it was presented (sung or spoken). It was found that learning digits by singing on a simple melody rather than merely speaking is detrimental to recall, be they presented in a sung or a spoken form, whereas singing has no consequence (either good or bad) on word recall (Jellison & Miller, 1982).

We (Racette & Peretz, submitted, a) recently conducted a study that examined whether singing is better than speaking in normal listeners, depending on the mode of presentation and production (sung vs spoken). The study was based on an oral learning of unfamiliar songs, in three different conditions. In the first condition, the participant listened to the sung version of the lyrics and had to sing them back. This condition will be called the sung-sung condition. In the second condition, the sung-spoken condition, the participant listened to the sung version of the lines and had to recite lyrics, without singing. The comparison of these two conditions aimed at determining the effect of music on production. In the third condition, the divided-spoken condition, the participant listened to the spoken lyrics and recalled only the lyrics. In this condition, presentation was defined as divided because, as the lyrics were spoken, the corresponding melody was sung on /la/ in the background. Consequently, when the lyrics were spoken, the context was equivalent than when lyrics were sung, since the melody was presented in both cases. Thus, the comparison of the sung-spoken and the divided-spoken conditions aimed at determining the effect of music at encoding.

Thirty-six university students participated, half being nonmusicians and half being music students. Participants learned one different song in each of the three conditions following an adaptive procedure. Songs selected for the study had eight lines that were taken from real songs composed by a folk-singer, but that were unfamiliar to all participants. The percentage of correctly recalled words (all three conditions), and musical notes (sung-sung condition) were calculated.

The first surprising finding was that musicians did not recall more words and notes than nonmusicians. This might be explained by the fact that musicians usually learn a song with the score. In the procedure used here, participants could only rely on the auditory code of the song, which is also familiar to nonmusicians. Therefore, musicians had no advantage over nonmusicians in an oral learning procedure, when having no possibility to use a visual support. When the data of the two groups were pooled together the sung recall was significantly lower than both spoken recalls. This means that music interfered with word recall on production. Moreover, because there were not more words recalled in the sung-spoken condition than in the divided-spoken conditions, there was no facilitation of music at encoding either. The results suggest that lyrics and melody of a song are represented in independent codes in memory. Participants would have to access both the melody and the lyrics, making singing a dual task, at least in the first steps of learning.

To summarize, studies in normal listeners have shown that reduced speed, repetition and simplicity of music, are elements that may help to recall words of songs. Yet, when a sung text is presented as fast as speech, when melodies are complex, when listeners have to produce a sung response, or when text is presented against a melodic background, the advantage of singing over speaking disappears. In other words, a song per se does not grant any actual advantage to text in memory, over text alone.

These findings with normal subjects raise questions regarding the classical observation that aphasic patients are able to sing words that are unable to pronounce otherwise. In fact, these observations are anecdotal. They were not substantiated by quantitative data of patients' production. The only study that did so does not support the idea that music facilitates word production. Cohen and Ford (1995) examined the production of 12 patients who became aphasic after a unilateral left-hemisphere vascular accident. Patients were asked to choose three songs from a list of eight songs they had sung in therapy over the previous three months. Patients had to produce the words of the choruses of the chosen songs under three experimental conditions, that is, spoken naturally (without any support), spoken with a steady drumbeat accompaniment, and sung accompanied with the melody played on a keyboard. Content, error types, and number of intelligible words per minute were the dependent variables. It was found that the speech content and error types did not differ across conditions, but that word intelligibility was higher when utterances were spoken without any support, with respect to when sung or spoken accompanied with a drumbeat. However, several methodological problems weaken the conclusions to be drawn. To name a few, the type and severity of aphasia of the patients were not specified. It is unknown how impaired these patients were in their expressive speech abilities. The group data may not be representative of how each patient performed in the different conditions. For instance, the averaging of performance may create effects that do not reflect any of the individual performance patterns, or may cancel out effects that would have been significant at the individual level (see Caramazza & McCloskey, 1988). Also, as was suggested by the authors themselves, the word intelligibility index (i.e., the average number of intelligible words divided by the average duration of each condition) could have been compromised in the rhythm and melody conditions because judges had to listen to recorded speech with a drumbeat or electric keyboard in the background. Masking effects could thus be involved in the finding of lower intelligibility in these conditions. Another important factor is that the word intelligibility index was only an approximation of the patients' production, because the whole set of productions was not analysed. Rather, a random sample taken from each patient in each condition was examined, which rendered the productions not necessarily comparable from one condition to another, or from one patient to another. Finally, performance on the melody of the songs was not assessed, so it is unknown if singing with the words was detrimental because patients had to produce both melody and words (a double task), or because words themselves were more difficult to produce while singing than while reciting with accompaniment. In addition, given that amusia is more often associated to aphasia than not, the presence of amusia, in some, or all of the patients, cannot be ruled out: A double deficit (amusia + aphasia) could, in itself, explain why the singing condition was least succeeded.

We recently revisited this question of singing in expressive aphasia and reported the cases of two aphasic patients in whom we assessed singing and speaking abilities within the same utterances (Hébert & al., 2003; Peretz & al., 2004). The first patient, CC, was a severely nonfluent aphasic patient who became aphasic after a stroke. Two experiments examined familiar and novel materials, respectively. CC had to repeat sung words (i.e., sung condition), spoken words (i.e., spoken condition), or melodies on the syllable "la" (i.e., music condition). Productions were analysed in terms of words and notes produced, in order to establish whether or not music imposes a load on memory and production, as it can occur in text recall. The findings showed that word production was comparable in the sung and the spoken conditions, with both familiar (Figure 1) and unfamiliar (Figure 2) materials. Also, CC was as competent as his controls for producing the music, and there was no additional cost to produce the music with the words with respect to the music alone.

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insert figure 1 about here

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insert figure 2 about here

The same findings were essentially replicated in the second patient, GD, who suffered from primary progressive aphasia. GD was tested on familiar material only since he was too deteriorated at the cognitive level to be tested on novel songs. His production of sung and spoken text was comparable in terms of number of syllables correctly repeated. His production of notes was significantly higher than for text, and comparable in the sung and music conditions. Also, in both cases the same error types were found on spoken and sung words.

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insert figure 3 about here

These two patients, having word-finding difficulties from different etiologies, point to the idea of separate codes for language and music in songs, rather than to granting songs a special status in the cognitive auditory system. The fact that non-fluent aphasic patients are able to sing, as reported previously, could therefore stem from the mere observation that their rote memory of automatic material, such as songs, is superior to their performance in generative tasks, such as spontaneous speech. This was indeed the case for CC and GD.

In another study (Racette & Peretz, in preparation), we examined the production of sung and spoken words of aphasic patients following the same paradigm as the one described earlier in normal listeners, and that involved the production of sung or spoken words in three conditions (sung-sung, spoken-sung, divided-spoken). Eight patients suffering from a variety of expressive aphasia (going from anomia to severe mixed aphasia) after a left-sided brain lesion were tested.

There was no difference between conditions. Thus, singing did not improve word production compared to speaking. This was true for the quantity of words produced but also for the types of errors in the different conditions. Moreover, aphasic patients did not produce more words than notes. The same profile was obtained in subsequent experiments using familiar material. Hence, there were as few words of familiar songs repeated by singing or by speaking. Even if songs are naturally sung with both the lyrics and the melody, there was no cost of producing the lyrics alone. This again suggests that the words and the melody are accessed separately in memory for songs.

Would these findings constitute grounds for discontinuing the use of Melodic Intonation Therapy in speech therapy or music therapy sessions? We would like to advocate quite the opposite. First of all, the fact that empirical studies point to the independence between language and music suggests that a possible transfer of skills acquired from singing towards speaking has real potential to occur. The suggestion of a special right-hemisphere competence for singing with words, which would involve mechanisms different than for speaking, would represent a serious clinical obstruction to therapeutic success. For instance, if patients had to learn words in songs in therapy, they would then have to learn not to sing those words for a transfer from singing to speaking to occur in their daily life. This type of rehabilitation would not constitute a very sensible strategy. The suggestion of special mechanisms for singing words and speaking would also stand in contrast with the increasingly growing (empirical and brain imaging) evidence on the independence of language and music neural networks.

Secondly, studies did show that presentation of a sung text, in a natural context (i.e., when songs are not artificially compressed for faster presentation) and with normal (simple and repetitive) melodies, is superior to a spoken text on recall, or at least is not detrimental to it. For instance syllable lengthening, which is an acoustic correlate of speed reduction in singing, helps nonfluent aphasic patients when they use the Melodic Intonation Therapy: The longer the syllables are, the more phrases are produced by patients (Laughlin, Naeser, & Gordon, 1979). Singing generally enhances fluency and word intelligibility of patients with speech disorders such as dysarthria or stuttering, possibly or partly via such mechanisms, although rigorous empirical studies are still lacking (Cohen, 1988; Colcord & Adams, 1979; Healey, Malard III, & Adams, 1976; Pilon, McIntosh, & Thaut, 1998).

Studies using language pathologies other than aphasia are crucially needed. In particular, one common characteristic of the patients examined in our studies is that they all had word-finding difficulties. The benefits of singing over speaking could well be more apparent in other language pathologies where the disorder involves supra-segmental (beyond the word) impediments. For instance, we (Hébert & Béland, unpublished data) examined the case of a stutterer and compared his fluency during sung, spoken, and spoken-paced-with-a-metronome renditions of the same texts. While in terms of percentage of words the advantage of sung words over spoken was modest (but nevertheless significant, in the order of about 5% and 15% for familiar and unfamiliar songs, respectively), it was when listening to his productions that the difference between these conditions was astonishing. The improvement could not be explained by speed reduction, since word production was faster when the patient spoke to the pulse of a metronome (and therefore, was not singing per se), and the performance in the latter condition was comparable to when singing. Thus, although improvement did occur when singing, the singing per se did not give this advantage, since metronome-paced speech was as good as singing. However, maybe some component (as yet to be found) that encompasses the word level, and that is common to singing and metronome-paced speech, is responsible for these effects.

Another study (Kempler & Van Lancker, 2002) examined the intelligibility in a dysarthric patient with Parkinson disease in spontaneous speech, reading aloud, repetition, repeated singing, and spontaneous singing. The singing stimuli (both repeated and spontaneous) were conversational phrases such as "It's a small village", similar to what is used in MIT. Not surprisingly, the spontaneous speech was found less intelligible than the other conditions, which did not differ significantly from each other. However, an interesting finding was that spontaneous singing was louder than the other conditions. Dysfluencies were also more frequent in spontaneous speech than in the other conditions. Disturbance in speech rate and reduced speech volume have been described as a prominent and even as an initial clinical feature of Parkinson disease. Speech impairments in this disease also include imprecise articulation, prosodic abnormalities, monotone, reduced stress, monoloudness, imprecise consonants, inappropriate silences, short rushes, harsch voice, continuous breathiness, pitch level disturbances, and variable rate, to name but a few. Therefore, even if in terms of number of words singing bore no advantage over speaking, the communication benefits that could be gained with music in therapy (via MIT or active music therapy) for this population are hardly doubtful. And this is exactly what Pacchetti et al. (2000) have shown. They compared physical therapy sessions (that included passive stretching, specific motor tasks, and strategies to improve balance and gait) with active music therapy sessions (that included choral singing, voice exercise, rhythmic and free body movements, and active music involving collective invention). While physical therapy produced significant improvement over music therapy for rigidity, music therapy produced significant improvement on bradykinesia (i.e., at a motor level), as well as on happiness, activities of daily living and quality of life, over physical therapy.

These studies bring about two further points: the fluency issue and additional benefits from speech and music therapy. Fluency is an ill-defined concept that is difficult to measure empirically and its corresponding acoustic cues are unknown (see Gordon, 1988). Rather, what we are aware of are fluency disruptions. Although fluency can be thought as applying to the word level (like in stuttering, for instance), it is most useful to describe prosody, or phrase contour (i.e., beyond the word level). In our studies reported here (aphasic and stutterer patients), the singing conditions yielded a strong impression of fluency that was not captured by the number of words or syllables produced. Therefore, the impression of fluency in singing, presumably produced by the smooth legato between words (i.e., no or few pauses), certainly contrasts with the limited and jerky spontaneous speech output of nonfluent aphasic patients, stutterers, and possibly patients with Parkinson disease. A therapy based on the exaggeration of prosody, perhaps by singing, may provide grounds for better modelling of sentence production.

Finally, additional benefits may be provided by music in therapy. First, because aphasic patients do not necessarily suffer from a music disorder (Hébert et al., 2003; Peretz et al., 2004), producing musical notes alone is still a good way for them to produce vocal sounds, and incidentally developing proper breathing and increase in volume. Second, a treatment emphasizing the rhythmic support of speech may improve repetition to a greater extent than the melodic support (Boucher, Garcia, Fleurant & Paradis, 2001). Finally, most aphasic patients seem to enjoy singing, which motivates them to participate in sessions and keeps their spirits high.

Music and language have to be compared on similar levels to determine if they share or not the same underlying processes. When comparing production of sung and spoken words, it was suggested that there is a unique speech code for words, be they sung or spoken. This verbal code would be separated from the musical code for musical notes production. Therefore, oral production of words and music in neurologically intact participants and in aphasic patients gave additional support for independent representations of music and language in memory for songs. However, the extent of inter-influence between music in language in songs, and how one can benefit from the presence of the other when damaged, because of the strong association between the two, has to be studied further.

Acknowledgements

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References

Albert ML, Sparks RW, Helm NA. (1973). Melodic Intonation Therapy for Aphasia. Archives of Neurology; 29: 130-1.

Assal, G. Wernicke's aphasia without amusia in a pianist. Rev Neurol (Paris) 1973; 129: 251–255.

Assal G, Buttet J, Javet RC. Aptitudes musicales chez les aphasiques. Rev Med Suisse Romande 1977; 97: 5-12.

Ayotte, J., Peretz, I., Rousseau, I., Bard, C., & Bojanowski, M. Patterns of music agnosia associated with middle cerebral artery infarcts. Brain 2000; 123: 1926–1938.

Basso A, Capitani E. Spared musical abilities in a conductor with global aphasia and ideomotor apraxia. J Neurol Neurosurg Psychiatry 1985; 48: 407-12.

Belin P, VanEeckhout Ph, Zibovicius M, Remy Ph, François C, Guillaume S, Chain F, Rancurel G, Samson Y. Recovery from nonfluent aphasia after melodic intonation therapy: A PET study. Neurology 1996; 47: 1504-11.

Bergeson, TR & Trehub, SE. Absolute pitch and tempo in mother's sons to infants. Psych Sci 2002; 13: 72–75.

Boucher V, Garcia LJ, Fleurant J, Paradis J. Variable efficacy of rhythm and tone in melody-based interventions: Implications for the assumption of a right-hemisphere facilitation in non-fluent aphasia. Aphasiology 2001; 15: 131-149.

Cadalbert, A., Landis, T., Regard, M., & Graves, R. E. (1994). Singing with and without words: hemispheric asymmetries in motor control. J Clin Exp Neuropsychol, 16(5), 664-670.

Caramazza A, McCloskey M. The case for single-patient studies. Cognitive Neuropsychology 1988; 5: 517-27.

Cohen NS. The use of superimposed rhythm to decrease the rate of speech in a brain-damaged adolescent. J Music Ther 1988; 25: 85-93.

Colcord RD, Adams MR. Voicing Duration and Vocal SPL Changes Associated With Stuttering Reduction During Singing. J Speech Lang Hear Res 1979; 22: 468-79.

Crowder, R. G., Serafine, M. L., & Repp, B. (1990). Physical interaction and association by contiguity in memory for the words and melodies of songs. Mem Cog, 18, 469–476.

Dickson, D. & Grant, L. (2003). Physics Karaoke: why not?. Physics Education, 38 (4), p. 320-323

Dowling, W. J. (1984). Development of musical schemata in children's spontaneous singing. In W. R. Crozier & A. J. Chapman (Eds.), Cognitive processes in the perception of art (pp. 145–163). Amsterdam: North-Holland.

Dowling, W. J., & Harwood, D. (1986). Music cognition. New York: Academic Press.

Epstein, C. M., Meador, K. J., Loring, D. W., Wright, R. J., Weissman, J. D., Sheppard, S., et al. (1999). Localization and characterization of speech arrest during transcranial magnetic stimulation. Clin Neurophysiol, 110(6), 1073-1079.

Gordon JK. The fluency dimension in aphasia. Aphasiology 1998; 12: 673-88.

Griffiths TD, Rees A, Witton C, Cross PM, Shakir RA, Green GG. Spatial and temporal auditory processing deficits following right hemisphere infarction. A psychophysical study. Brain 1997; 120: 785-94.

Halpern, A. R. (1988). Perceived and imagined tempos of familiar songs. Music Perception, 6, 193–202.

Halpern, A. R. (1989). Memory for the absolute pitch of familiar songs. Mem Cog, 17, 572–581.

Healey EC, Mallard III AR, Adams MR. Factors contributing to the reduction of stuttering during singing. J Speech Lang Hear Res 1976; 19: 475-80.

Hébert S, Peretz I. Are text and tune of familiar songs separable by brain damage? Brain Cogn 2001; 46: 169-75.

Hébert, S., Racette, A., Gagnon, L., & Peretz, I. Revisiting the dissociation between singing and speaking in expressive aphasia. Brain 2003; 126, 1836-1850.

Heiss WD, Kessler J, Thiel A, Ghaemi M, Karbe H. Differential capacity of left and right hemispheric areas for compensation of poststroke aphasia. Ann Neurol 1999; 45: 430-8.

Jacome, D. E. (1984). Aphasia with elation, hypermusia, musicophilia and compulsive whistling. J Neurol Neurosurg Psychiatry, 47(3), 308-310.

Jellison, J. A. & Miller, N. L. (1982). Recall of digit and word sequences by musicians and nonmusicians as a function of spoken or sung input and task. J Music Therapy, XIX (4), 194-209.

Kempler D. & Van Lancker D (2002). Effect of speech task on intelligibility in dysarthria: A case study of Parkinson's disease. Brain Lang 2002; 80: 449-464.

Keith RL, Aronson AE. Singing as therapy for apraxia of speech and aphasia: Report of a case. Brain Lang 1975; 2: 483-8.

Kilgour AR, Jakobson LS, Cuddy LL. Music training and rate of presentation as mediators of text and song recall. Mem Cognit 2000; 28: 700-10.

Laughlin, S. A., Naeser, M. A., & Gordon, W. P. (1979). Effects of three syllable durations using the melodic intonation therapy technique. J Speech Hear Res, 22(2), 311-320.

Levitin, D. J. (1994). Absolute memory for musical pitch: evidence from the production of learned melodies. Percept Psychophys, 56, 414–423.

Levitin, D. J., & Cook, P. R. (1996). Memory for musical tempo: additional evidence that auditory memory is absolute. Percept Psychophys, 58, 927–935.

Luria, A.R. (1973). The man with a shattered world. Translated by L. Solotaroff. London: Cape, pp.154-5.

Luria, A. R., Tsvetkova, L. S., & Futer, D. S. (1965). Aphasia in a composer (V. G. Shebalin). Journal of Neurology Sciences, 2, 288–292.

Marin, O. S., & Perry, D. W. (1999). Neurological Aspects of music perception and performance. In *The psychology of music*. Los Angeles.

Ostwald, P. F. (1973). Musical behavior in early childhood. Developmental Medicine & Child Neurology, 15, 367–375.

Pacchetti C, Mancini F, Aglieri R, Fundarò C, Martignoni E, & Nappi G. (2000). Active music therapy in Parkinson's disease: An integrative method for motor and emotional rehabilitation. Psychosomatic Medicine 2000; 62: 386-393.

Papanicolaou AC, Moore BD, Deutsch G, Levin HS, Eisenberg HM. Evidence for right-hemisphere involvement in recovery from aphasia. Arch Neurol 1988; 45: 1025-9.

Peretz I, Belleville S, Fontaine F. Dissociations entre musique et langage après atteinte cérébrale: un nouveau cas d'amusie sans aphasie. Can J Exp Psychol 1997; 51: 354-67.

Peretz I, Radeau M, & Arguin M. (2004). Two-way interactions between music and language: evidence from priming recognition of tune and lyrics in familiar songs. Mem Cog 32(1):142-52.

Peretz I, Kolinsky R, Tramo M, Labrecque R, Hublet C, Demeurisse G, Belleville S Functional dissociations following bilateral lesions of auditory cortex. Brain 1994; 117: 1283-1302.

Peretz I, Gagnon L, Hébert S, & Macoir J. (2004). Singing in the brain: Insights from cognitive neuropsychology. Music Perception 2004; 21: 373-390

Piccirilli, M., Sciarma, T., & Luzzi, S. (2000). Modularity of music : Evidence from a case of pure amusia. J Neurol Neurosurg Psychiatry, 69, 541–545.

Pilon MA, McIntosh KW, Thaut MH. Auditory vs. visual speech timing cues as external rate control to enhance verbal intelligibility in mixed spastic-ataxic dysarthric speakers: a pilot study. Brain Inj 1998; 12: 793-803.

Racette, A. & Peretz, I. (submitted, a). Learning lyrics: To sing or not to sing.

Racette, A. & Peretz, I. (in preparation). Making expressive aphasics sing: Sing along!.

Rubin DC. Very long-term memory for prose and verse. Journal of Verbal Learning & Verbal Behavior 1977; 16: 611-21.

Ryding, E., Bradvik, B., & Ingvar, D. H. (1987). Changes of regional cerebral blood flow measured simultaneously in the right and left hemisphere during automatic speech and humming. Brain, 110 (Pt 5), 1345-1358.

Serafine ML, Crowder RG, Repp BH. Integration of melody and text in memory for songs. Cognition 1984; 16: 285-303.

Serafine ML, Davidson J, Crowder RG, Repp BH. On the nature of melody-text integration in memory for songs. J Mem Lang 1986; 25: 123-135.

Signoret, J. L., van Eeckhout, P., Poncet, M., & Castaigne, P. (1987). [Aphasia without amusia in a blind organist: Verbal alexia-agraphia without braille]. Rev Neurol (Paris), 143, 172–181.

Sparks R, Helm N, Albert M. Aphasia rehabilitation resulting from melodic intonation therapy. Cortex 1974; 10: 303-316.

Steinke WR, Cuddy LL, Jakobson LS. Dissociations among functional subsystems governing melody recognition after right hemisphere damage. Cognitive Neuropsychology 2001; 18: 411-437.

Therapeutics and Technology Assessment subcommittee of the American Academy of Neurology. Assessment: Melodic intonation therapy. Report of the Therapeutics and technology assessment subcommittee of the American Academy of Neurology. Neurology 1994; 44: 566-8.

Tzortzis, C., Goldblum, M. C., Dang, M., Forette, F., & Boller, F. (2000). Absence of amusia and preserved naming of musical instruments in an aphasic composer. Cortex, 36(2), 227-242.

Vignolo, L. A. (1969). Auditory agnosia : A review and report of recent evidence. In A. L. Benton (Ed.), *Contributions to clinical neuropsychology* (pp. 172-208). Chicago: Aldine.

Vignolo, L. A. (1982). Auditory agnosia. Philos Trans R Soc Lond B Biol Sci, 298(1089), 49-57.

Vignolo, L. (2003). Music agnosia and auditory agnosia. Dissociations in stroke patients. Annals of the New York Academy of Sciences. 999: 50-7.

Wallace WT. Memory for Music: Effect of Melody on Recall of Text. J Expe Psychol Learn Mem Cogn 1994; 20: 1471-1485.

Wilson, S. J., & Pressing, J. (1999). Neuropsychological assessment and the modeling of musical deficits. In R. R. Pratt & D. Erdonmez Grocke (Eds.), Music medicine and music therapy: Expanding horizons (pp. 47–74). Melbourne: The University of Melbourne.

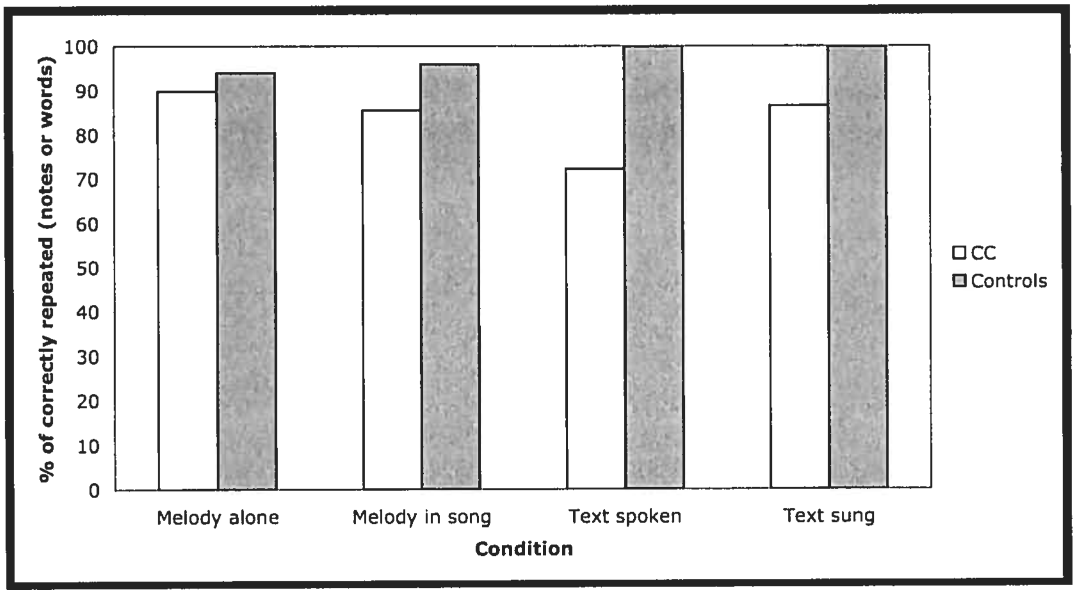
Yamadori A, Osumi Y, Masuhara S, Okubo M. Preservation of singing in Broca's aphasia. J Neurol Neurosurg Psychiatry 1977; 40: 221-224.

Figure Captions

Figure 1. Percentage of correctly repeated notes or words by CC and his matched controls, with respect to the experimental condition, for familiar songs.

Figure 2. Percentage of correctly repeated notes or words by CC and his matched controls, with respect to the experimental condition, for unfamiliar songs.

Figure 3. Percentage of correctly repeated syllables with respect to the experimental condition for GD.



% of correctly repeated (notes or words)
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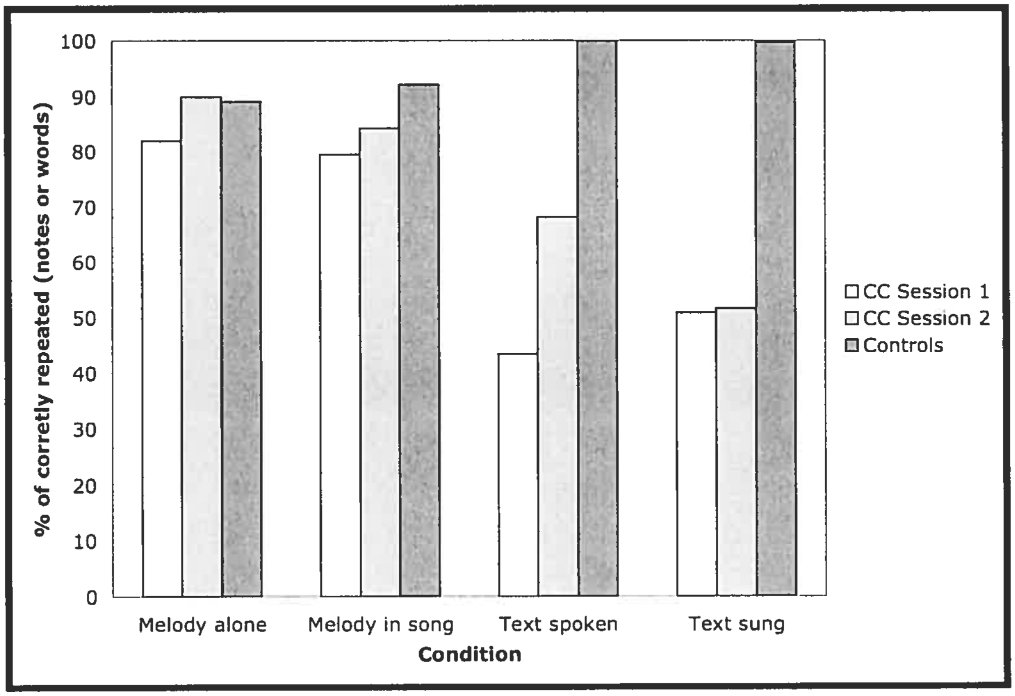
60
50
40
30
20
10
0
Melody alone
Melody in song
Text spoken
Text sung
Condition
CC
Controls


% of corretly repeated (notes or words)
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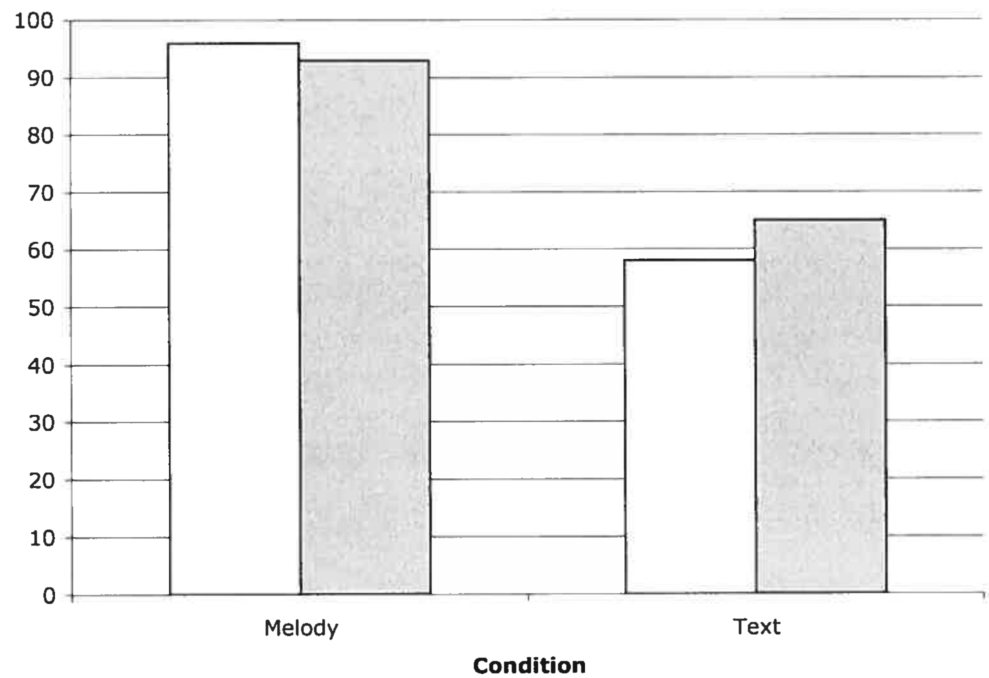
Melody alone
Melody in song
Text spoken
Text sung
Condition
CC Session 1
CC Session 2
Controls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MOT DE LA FIN

Dans cette thèse, nous avons vu que, lorsque des chansons sont apprises sans support externe, le fait d'entendre les mots chantés ou de chanter les mots ne garantit pas un meilleur rappel ou une meilleure répétition du texte. Ces résultats suggèrent que la musique n'aide pas la mémoire et la production verbale. Les résultats constituent une indication supplémentaire que musique et langage sont représentés séparément en mémoire et ce, même dans le cas des chansons, où paroles et mélodie sont apprises ensembles. Dans la présente thèse, c'est par l'étude de la production du chant, que cette conclusion est suggérée. L'indépendance entre les composantes verbales et musicales d'une chanson est retrouvée lors des premières étapes de l'apprentissage de chansons non familières mais aussi en production de chansons familières, où parole et mélodie ont été maintes fois répétées ensemble. Même dans ce cas, paroles et mélodies ne semblent pas avoir été intégrées sous un code unique, correspondant à de la parole chantée, qui pourrait alors être difficilement dissocié.

C'est lorsque les patients aphasiques peuvent produire les mots à l'unisson que le chant est bénéfique. La production à l'unisson est fréquemment utilisée dans les phases initiales des thérapies en orthophonie mais aussi comme structure externe à la parole chez les bègues. Ici, l'avantage du chant sur la parole à l'unisson trouve plusieurs explications possibles. La possibilité de synchroniser sa production avec celle d'une autre personne a permis aux patients présentant les aphasies les plus sévères de réduire significativement leur débit en chantant. Alors qu'ils ne ralentissaient leur production que de 15% en chantant seul, la production était ralentie d'environ 40% à l'unisson. Une production synchronisée peut donc obliger des patients aphasiques sévères à ralentir leur débit, leur permettant à la fois un meilleur contrôle moteur et une meilleure planification phonétique.

L'aide du chant n'est pas simplement due à la vitesse. Si c'était le cas, tout procédé externe pour ralentir le débit devrait améliorer la production des aphasiques. Or, la relation entre le débit et la proportion de mots intelligibles n'est pas simple. Il n'existe pas de lien direct entre la durée moyenne des syllabes produites et le pourcentage de mots correctement produits. Cette relation est même inexistante chez les patients présentant des aphasies plus modérés, bien que ceux-ci puissent aussi bénéficier du chant. L'utilisation d'un métronome pour ralentir la vitesse de production ne serait donc pas garante d'une amélioration de la communication. L'activité chorale semble toutefois un moyen de produire plus de mots adéquatement mais le transfert dans la vie de tous les jours s'avère un défi. La structure offerte par le chant faciliterait la synchronisation et diminuerait les exigences en planification chez les patients aphasiques. De plus, l'envie de chanter en chœur fait de la chorale une activité sociale de choix suite à un accident. Les patients ayant une difficulté à s'exprimer ont effectivement tendance à s'isoler. La musique devient une façon de retrouver la compagnie d'autrui et ainsi d'entraîner la communication.

La musique possède d'autres bienfaits qui ne peuvent être négligés. Ainsi, le chant diminue le nombre d'hésitations lors du rappel de mots chez des non-musiciens. La musique peut aussi donné aux patients ou aux étudiants l'envie de pratiquer un texte à produire et ainsi, à long terme, améliorer son apprentissage. L'avantage de la musique n'est donc pas strictement verbal mais aussi motivationnel. Il serait intéressant d'utiliser un entraînement à plus long terme, avec des étudiants et des patients, afin d'observer l'évolution dans l'association entre paroles et mélodie. La musique est aussi connue pour augmenter le bien-être et stimuler l'attention.

Des questions demeurent quant aux apports différentiels de la voie mélodique et de la voie temporelle formant la musique, la localisation des paroles et des mélodies de chansons et l'utilisation possible d'un karaoke, où la musique est entendue sans les paroles (qui sont le plus souvent écrites). L'automatisation de l'analyse de production, que ce soit pour l'analyse des mots, des notes et de la fluidité, faciliterait les études de production. Toutefois, l'oreille humaine, bien que subjective, demeure un juge valide pour traiter l'intelligibilité des mots et la justesse des notes.

L'étude de conditions et de matériels variés auprès d'une population aphasique diversifiée constitue la grande contribution de cette thèse. Nos résultats, négatifs en grande partie, viennent ébranler des croyances fortement ancrées dans la société, celle que la musique peut être mise au service du langage. L'apport de la thèse est de démontrer, aussi bien chez les personnes sans histoire neurologique que chez des patients dont la production du langage est atteinte, que la musique n'est pas magique!

APPENDICE

Apport des auteurs

Article 1 : « Les amusies »

Amélie Racette : Recherche de la littérature, rédaction

Isabelle Peretz : Supervision lors de la rédaction

Article 2 : « Leaning song lyrics : To sing or not to sing? »

Amélie Racette: Recherche et analyse de la littérature, création du matériel, participation au choix de la méthodologie, collecte des données, analyse des résultats, rédaction.

Isabelle Peretz : Choix de la problématique, supervision lors de la conceptualisation, de l'analyse et de la rédaction.

Article 3 : « Revisiting the dissociation between singing and speaking in expressive aphasia »

Sylvie Hébert: Analyse de la littérature, développement de la méthodologie, collecte des données, analyse des résultats, rédaction.

Amélie Racette : Participation à la recherche de la littérature, à la collecte des données, à l'analyse des données et corrections lors de la rédaction.

Lise Gagnon : Recrutement et évaluation du patient, participation à la collecte des données et à la rédaction.

Isabelle Peretz : Développement de la problématique, supervision lors de l'interprétation et de la rédaction.

Article 4 : « Making non-fluent aphasics speak : Sing along! »

Amélie Racette: Recherche et analyse de la littérature, création du matériel, participation au choix de la méthodologie, collecte des données, analyse des résultats, rédaction.

Isabelle Peretz : Choix de la problématique, supervision lors de la conceptualisation, de l'analyse et de la rédaction.

Céline Bard : Radiologue ayant permis l'obtention et la description des images cérébrales des patients.

Article 5 : « Should we make aphasic patients sing? »

Sylvie Hébert: Recherche et analyse de la littérature, rédaction.

Amélie Racette : Participation à la recherche de la littérature, rédaction du résumé des études sur le groupe de normaux et d'aphasiques, correction lors de la rédaction.

Isabelle Peretz : Participation à la rédaction.