10 Is music autonomous from language? A neuropsychological appraisal

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INTRODUCTION

Music and language are universal among humans, and both employ richly structured auditory and motor patterns. Since music and language are the two primary acoustic communicative systems of our species, their similarities and differences as cognitive domains have long interested scholars. (e.g. Aiello, 1994; Albert, Sparks & Helm, 1973; Besson, Faïta, & Requin, 1994; Bernstein, 1976; Blacking, 1976; Clarke, 1989; Darwin, 1871; Handel, 1989; Judd, Gardner & Geschwind, 1983; Lerdahl & Jackendoff, 1983; Levman, 1992; Nettl, 1956; Rousseau, 1761; Selkirk, 1984; Sergent, 1993; Sloboda, 1985; Sundberg & Lindblom, 1976; Sundberg, Nord & Carlson 1991; Trehub & Trainor, 1993). These contributions highlight the diversity of fields which have addressed this issue, from philosophy to the social, psychological, and biological sciences.

This chapter focuses on aspects of the music-language relation which are amenable to empirical study. We assume that the mental domain of "music" is not an indivisible whole, but rather a confluence of interacting cognitive processes. In keeping with this view, each section of the chapter treats a selected aspect of musical structure, reviewing evidence which suggests whether this aspect engages domain-specific processes or processes which might be shared with language. The topic of music reading and its relation to linguistic reading is not covered here, as it has been treated at length by other authors (the interested

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reader is referred to Judd et al. 1983; Fasanaro, Spitaleri, & Valiani, 1990; Sergent, Zuck, Terriah, & MacDonald, 1992; Signoret, Van Eeckhart, Poncet, & Castaigne, 1987; Stanzione, Grossi, & Roberto, 1990). Finally, we note that this chapter emphasises perceptual processes. This reflects a decision to dwell more fully on selected topics, rather than a belief that production processes are less deserving of study.

Because neuropsychology provides empirical evidence regarding the fractionation of cognitive processes via patterns of dissociation and association after brain damage, data from this field play a prominent role in this review. In this light, two types of neurologic disorder are particularly relevant: amusia and aphasia. "Amusia" refers to an acquired disorder of music perception or production following brain damage, while "aphasia" refers to certain disorders of language secondary to neurological damage. In both cases, the problems are not a consequence of peripheral neuropathy, but of damage to central processing mechanisms.

In the past, cases of amusia without aphasia and aphasia without amusia have been cited as evidence that music and language have little cognitive overlap (Marin, 1982; Sergent, 1993). Yet such a conclusion is likely to be premature. First, the claim makes no reference to the processing subcomponents of music and language. Second, cases of aphasia without amusia are generally exceptional individuals such as conductors and composers (e.g. Basso & Capitani, 1985; Luria, Tsvetkova, & Futer, 1965), whose musical talents may not be representative of musical abilities shared by musicians and non-musicians. Third, diagnosis of "amusia without aphasia" does not rule out language deficits, because "aphasia" does not include all disorders of language processing. For example, the Boston Diagnostic Aphasia Examination (Goodglass & Kaplan, 1983) does not examine prosodic perception, and accordingly, disorders of prosody are not classified as aphasia.

Amusic subjects can teach us a great deal about the organisation of music cognition and its neural substrates, and about the relation of music to other cognitive domains. It must be remembered, however, that tests for dissociations between music and other domains can only reflect the particular tasks administered to subjects. In this light, testing musically (or linguistically) impaired subjects on maximally comparable musical and linguistic tasks has dual benefits: it can yield greater specificity in the characterisation of a particular subject's deficit(s), and sharpen our understanding of the role of implicated neural regions in both musical and linguistic processing.

AUDITORY SCENE ANALYSIS

In most natural circumstances, acoustic elements reach the ear in a disordered mixture. Assigning each element to a particular sound source is a necessary part of auditory perception. Grouping mechanisms akin to the Gestalt principles of organisation seem to help solve this parsing problem. In this early analysis, currently referred to as primitive auditory scene analysis (Bregman, 1990), sounds that share certain properties or regularities are grouped together in a single stream or auditory object. Higher level schemas (or knowledge of the typical properties of the perceptual elements) may assist scene analysis by confirming or restoring the possible organisation. This conceptualisation is intended to apply universally: that is, to voices, music, and speech sounds alike (Bregman, 1990).

This general account of auditory perceptual organisation has been seriously questioned by researchers working on speech signals (Liberman & Mattingly, 1989; Remez, Rubin, Berns, Pardo, & Lang, 1994). They argue, on the basis of substantial empirical evidence (see Remez et al. 1994, for a recent review), that perceptual organisation of speech depends on sensitivity to time varying acoustic patterns that are specific to phonologically governed sources of sounds. Perceptual organisation of speech appears autonomous from that involved in non-speech sounds.

Thus, despite its parsimony and simplicity, the generalisability of the mechanisms involved in auditory scene analysis may not be warranted. Neuropsychological data should be particularly enlightening in this area. However, to our knowledge, auditory scene analysis has never been addressed in brain-injured patients or normal subjects by way of brain imaging techniques or laterality paradigms. The only exception of which we are aware used evoked potentials (Alain & Woods, 1994) and basically confirmed the biological relevance of auditory scene analysis mechanisms. In this study, only unnatural simple sound patterns were used. Thus, the question of neural specificity of speech and non-speech domains remains open for future investigations.

MELODY

Melody, the perceptually coherent patterning of pitch over time, has many distinct aspects (Meyer, 1973; Narmour, 1991a), only three of which will be considered in this chapter: melodic contour, the use of discrete pitch categories, and the Western European system of tonality.

MELODIC CONTOUR

Melodic contour is the general shape of a melodic line (its patterns of ups and downs in pitch direction over time), without regard to exact pitch intervals. The relevance of contour to musical organisation is evident in diverse musical traditions. In Bach, the melodic subject introduced at the beginning of a fugue is soon repeated at a higher or lower register. This repetition of the theme need not be an exact transposition: it can be a "tonal answer", which preserves the contour but not the precise intervals. In American folk ballads of the English tradition, variants of a tune can be divided into families, with contour as a prominent classifying feature (Seeger, 1966). Among the Wopkaimin of Central Papua New Guinea, songs that share a particular theme (e.g. sacred initiation songs) often share similar contours (Roberts, 1996). In fact, the role of contour in the organisation of melody is one of the few features of music to appear cross-culturally (Harwood, 1976).

Over the past 25 years, Dowling and others have demonstrated that contour is a salient feature in melodic perception, whose importance relative to exact interval patterns depends on multiple factors such as memory load, tonality, familiarity and length of the melody (Dowling, Kwak, & Andrews, 1995; Edworthy, 1985). Another line of research has focused on the processing of musical contour by young infants. In an operant same-different discrimination paradigm, infants are able to treat transposed versions of a melody as similar as long as the contour is preserved, despite changes in interval structure, while discriminating melodies on the basis of contour changes (Trehub, Thorpe & Morrongiello, 1987 and Trehub, Schellenberg & Hill, this volume). While the above research suggests the importance of contour to the *structure* of musical organisation and perception across ages, there is also research suggesting that musical contour may convey an *emotional* message to a listener (e.g. Clynes & Nettheim, 1982; Gerardi & Gerken, 1995).

In speech, the pattern of fundamental frequency (Fo) over time is a basic part of the organisation and perception of spoken language. This pattern is referred to as "intonation" rather than "contour", and contributes to marking the boundaries of structural units, distinguishing pragmatic categories of utterance (e.g. statement, question, command), and signalling focus (Beckman & Pierrehumbert, 1986; Bolinger, 1989; Lehiste, 1973; Price, Ostendorf, Shattuck-Hufnagel, & Fong, 1991). Intonational marking of phrase boundaries in speech appears to be perceptually significant for infants (Jusczyk, Hirsh-Pasek, Kelmer-Nelson, Kennedy, Woodward, & Piwoz, 1992), and the similarity to phrase boundary cues in music (pitch drop, slowing) has been noted (Jusczyk & Krumhansl, 1993).

Intonation also communicates intention and affect. In infant directed speech (known informally as "motherese"), highly salient intonational patterns are used to recruit the pre-verbal infant's attention and communicate approval, disapproval, soothing, etc. (Fernald, 1985, 1993; Fernald & Kuhl, 1987). Since infants must process intonation from speakers of different ages and sexes, their sensitivity to this signal is likely to be independent of the absolute frequency at which it occurs, just as infants show generalisation of contour across different pitch registers in music (Trehub et al. 1987). Sensitivity to intonation as an intentional and affective cue remains part of speech perception throughout life, and has been empirically studied by Ladd, Silverman, Tolkmitt, Bergmann, & Scherer (1985) and others.

Given the similarities of melodic contour and intonation, it seems reasonable to expect that their processing shares some cognitive and neural resources. While neuropsychological deficits in the processing of musical contour (Peretz, 1990) and linguistic intonation (Heilman, Bowers, Speedie, & Coslett, 1984)

have been reported independently, the association between the two types of processing has not been studied in a systematic fashion.

Amusics with melodic perception deficits provide an opportunity to test this issue. Specifically, one can examine the ability of amusic but non-aphasic patients to distinguish between sentences that differ only in their intonation, and between musical phrases derived from the intonational patterns of these sentences. A purely musical deficit should manifest itself in difficulty on the musical task, but success on the linguistic one: this would argue for the separability of melodic contour and speech intonation. On the other hand, a similar breakdown pattern across domains would suggest common processing.

We recently conducted an experiment which addressed this issue (Patel, Peretz, Tramo, & Labreque, in press). Thirty-four sentence pairs were recorded in French: each pair represented two lexically identical versions of a sentence, but differed in linguistic prosody. Twelve pairs constituted statement-question pairs (e.g. Il parle Français. / Il parle Français? He speaks French./He speaks French?). Twelve pairs constituted focus-shift pairs, involving a shift in the word which bore the focus of the sentence (e.g. Allez DEVANT la banque, j'ai dit. / Allez devant la BANQUE, j'ai dit. Meet me IN FRONT OF the bank, I said. / Meet me in front of the BANK, I said.). Ten additional sentence pairs were used to study the perception of timing (these "timing-shift" sentences will be discussed in the section on Grouping below).

In order to ensure that discrimination was based on intonation, all the statement-question pairs and half of the focus-shift pairs were acoustically adjusted to equalise patterns of syllable timing and loudness within each pair, yielding natural-sounding sentence pairs in which fundamental frequency was the only salient cue for discrimination. The other half of the focus-shift sentence pairs were left unmanipulated: here focal words were marked not only by pitch accents but by intensity and duration as well. These unmanipulated sentences served as controls, to determine if discrimination problems occurred in contrasting sentences of natural speech, where focus is signalled by multiple prosodic cues.

For the acoustically-controlled sentences, the fundamental frequency patterns of each sentence pair were used to generate two melodic sequences in which tones had the durational characteristics and pitch values of their parent syllables (tone amplitudes were set at a fixed value). Although the fundamental frequency of spoken language typically moves up and/or down within each syllable, the pitch of each tone was fixed at its parent syllables' mean Fo (plus two harmonics), giving the resulting melodic analogues a discrete intervalic structure. This made the melodic analogues sound much less speech-like than the original intonation patterns. No melodic analogues were made from the acoustically-uncontrolled focus-shift pairs, since the analogues, like their parent sentences, would have differed in parameters other than intonation (e.g. timing), thus compromising the specificity of the test for pitch discrimination. It should be noted that no attempt was made to make the pitches or intervals of the melodies correspond to the Western musical scale. This precluded the experiment from addressing the perception of tonality, but allowed it to address the perception of contour versus intonation in a precise fashion.

The linguistic and musical phrases were administered in separate parts of the experiment. The task was always to listen to a pair of phrases and classify the members of the pair as sounding the same or different (pairs could appear in either configuration, and replicates were included). The subjects, CN and IR, were female French-speakers with bilateral cortical lesions (due to stroke and surgery for aneurysms) and no aphasic problems: they were 40 and 37 years old and 7 and 9 years post-surgery, respectively. Both were raised in musical households, and were classified as amusic based on personal reports of post-surgical deficits in music perception and on performance on neuropsychological tests of music processing (Peretz, Kolinsky, Tramo, Labrecque, Hublet, Demeurisse, & Belleville, 1994). At the time of testing, CN's problems appeared to be primarily with music recognition, while IR had more basic melodic and rhythmic discrimination problems (Peretz, 1994 and forthcoming).

The results for CN, IR, and 8 age-and-education-matched controls can be seen in Figure 10.1. For the sake of clarity, the focus-shift category for language is represented only by focus-shift pairs that had musical analogues.

The Fisher exact probability test revealed that for both CN and IR, the proportions of correct responses on analogous linguistic and musical tasks was not significantly different across domains (statistical comparisons used raw scores, not percentages; controls also showed no significant difference across domains). Overall, the pattern of results suggests an association between

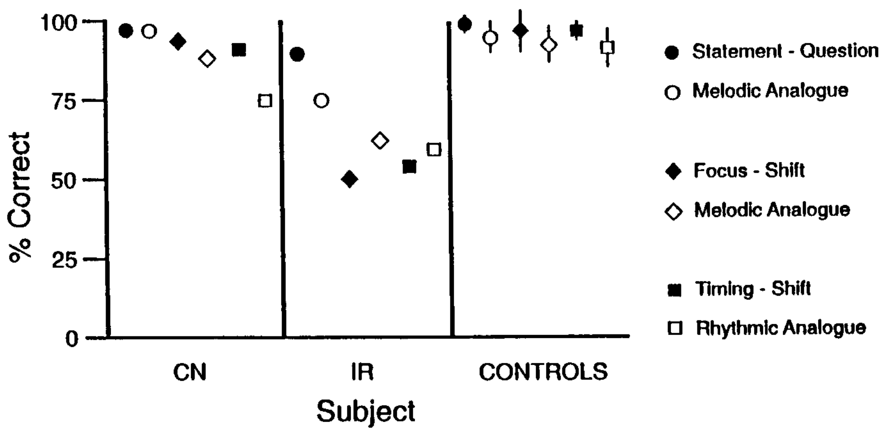

FIG. 10.1 Scores on analogous linguistic and musical tasks for CN, IR, and 8 controls, represented as percentages. Error bars on control scores represent standard deviation.

performance on musical contour and linguistic intonation tasks, arguing for some common neural contribution to both types of task.

The most surprising result of the study is IR's difficulty in discriminating focus-shift pairs in language (statistically she performed at the level of random guessing), a linguistic deficit which did not emerge in standard aphasia testing. Her difficulty cannot be attributed to artificiality in the stimuli, since her performance on "control" focus-shift pairs (not equalised for duration and intensity patterns) was just as poor. Neither can it be attributed to a failure to encode pitch: she performed well on statement-question discrimination in language and music, where she reported concentrating on the final pitch in the sequence. The focus-shift task, however, had the critical pitch located *within* the sequence. It is worth noting that IR performed well above chance on an additional task in which she listened to focus-shift sentences one at a time and identified the accented word. Thus, she can perceive sequence-internal pitch, but performs poorly on the focus-shift task and its musical analogue, both of which require pitch patterns to be maintained in memory. In other words, IR seems to have a deficit in mechanisms involved in the short term retention of musical contour and intonation (she also appears to have a deficit in the retention of temporal patterns in language and music: c.f. the section on 'Grouping', below).

CN, who performed well on the musical and linguistic discrimination tasks, has bilateral damage to the rostral and middle third of the superior temporal gyri, the middle temporal gyri, the temporal poles, and the right insula, with limited extension into the right inferior frontal gyrus, and the sparing of primary auditory cortex (Peretz et al. 1994). IR has more widespread temporal lobe damage on the left side (including primary auditory areas), and damage to the right inferior frontal cortex, suggesting that these regions may play an important role in the retention and comparison of pitch and temporal patterns in both musical and linguistic domains (details of CN's and IR's lesions, including CT scan images, can be found in Patel, Peretz, Tramo, and Labreque, in press). Details of IR's lesions are interesting in light of previous evidence that the right hemisphere plays a crucial role in musical contour perception (Peretz, 1990; Peretz and Babaï, 1992), and in light of recent metabolic neuroimaging data (from normal subjects) implicating right frontal circuits in the retention and comparison of pitches in both melodic phrases (Zatorre, Evans, & Meyer,1994) and syllables (Zatorre, Evans, Meyer & Gjedde, 1992). However, it should be kept in mind that IR had bilateral lesions, suggesting the interaction of brain regions in different hemispheres in prosodic and musical processing.

Of course, as with any case of functional association, the possibility exists that the processes in question are in fact neurally and functionally distinct, but are disrupted by the same lesion: this issue can only be resolved by further testing. We are aware of one previous report where right fronto-temporal damage (atrophy) led to deficits in musical and prosodic perception, but the relation between melodic and intonational processing was not studied in a controlled fashion (Confavreux, Croisile, Garassus, Aimard, & Trillet, 1992). It is also possible that the association between prosodic and musical processing seen in our subject IR is due to a general auditory short-term memory deficit which disrupts the retention of auditory patterns of any kind. Another study (Belleville & Peretz, forthcoming) reveals that IR has short-term memory deficits in a wide variety of musical and verbal tasks (including digit spans). Only further testing can reveal whether the resources used in short-term storage of prosodic and musical patterns are also relevant to other kinds of patterns of sound (e.g. environmental sounds).

One way to address the specificity of the prosody-music link is to test subjects known to have prosodic deficits (but no short-term memory problems) for their musical perception abilities. Cases of prosodic perception deficits following brain damage come to light much more frequently than cases of amusia. "Aprosodia" can be due to damage to the right or left hemisphere (Blonder, Bowers, & Heilman, 1991; Cancelliere & Kertesz, 1990; Ross, 1981) or to subcortical regions (Brådvik, Dravins, Holtås, Rosén, Ryding & Ingvar, 1991), but its relation to perception of music has yet to be investigated. Most of the studies to date focus on aprosodia as a deficit of affective perception, but recent work suggests that there may be a more basic underlying deficit in the perception of pitch and temporal cues (Van Lancker & Sidtis, 1992). This is supported by the finding that certain aprosodic subjects have problems with *linguistic* prosody (Baum, Daniloff, Daniloff, & Lewis, 1982; Emmorey, 1987; Heilman et al. 1984; Weintraub, Mesulam, & Kramer, 1981), suggesting that they can be fruitfully tested with the types of stimuli and tasks discussed here. An association between prosodic and musical processing in these subjects would provide further evidence for common neural resources in the processing of prosodic and musical pitch contours.

DISCRETE PITCH CATEGORIES

To avoid confusion, a distinction should be drawn at once between perception in terms of discrete categories and Categorical Perception (capitalised here for clarity). The latter refers to a particular psychophysical phenomenon in which stimuli lying along a physical continuum are perceived in discrete perceptual classes, *and* stimulus pairs of a given physical difference along this continuum are easily discriminated when they straddle a category boundary, but poorly (or not at all) discriminated when they lie within a category (Repp, 1984). However, it is important to note that perception in terms of categories does not require Categorical Perception: for example, the Thai language (and many others) makes a phonemic distinction between long and short vowels, implying that vowels are conceived and perceived in terms of discrete categories of length: yet Thai listeners do not show Categorical Perception for variation in vowel duration (Repp, 1984).

In music, pitch categories are of three basic kinds: pitch classes, pitch intervals, and chords. Absolute pitch possessors are able to label isolated pitches with respect to pitch class (Miyazaki, 1988), but recent detailed research (Burns & Campbell, 1994) suggests that this does not reflect Categorical Perception. On the other hand, Categorical Perception for intervals (Burns & Campbell, 1994; Burns & Ward, 1978) and for chords (Repp, 1984) has been demonstrated in musicians. The perception of musical pitch in terms of categories, however (as opposed to Categorical Perception per se) is likely to be shared by both musicians and non-musicians (Smith, Nelson, Grohskopf, & Appleton, 1994).

Pitch categories are not unique to music. Over half of the world's languages are "tone languages" (Crystal, 1987; Pike, 1948), meaning that the relative pitch of a syllable can change the lexical meaning of a word (e.g. the syllable "ma" in Mandarin Chinese can mean "horse", "hemp", "mother", or "scold", depending on its tone). In a tone language, a tone is specified by its relative height (e.g. *high, low*), inflection (e.g. *falling, falling-rising*), or both (e.g. *high-rising, low-rising*). The number of tones in a tone language varies between two (many African languages) and at least nine (Southern coastal Cantonese: Yung, 1991). Evidence for Categorical Perception of linguistic tones is mixed (Repp, 1984), yet logically tones *must* be conceived and perceived in discrete categories in order to accomplish their function.

Musical and linguistic pitch categories differ in at least one crucial respect: organisation with respect to a scale. In many cultures, musical pitches divide frequency space into discrete steps, separated by prescribed intervals. To our knowledge, no tone languages have been reported to show this feature. The greater rigidity of musical pitch relations could reflect the fact that musical pitches are used to make melodies, in which the relations between pitches over extended sequences is of central importance. Linguistic tones, in contrast, act as localised semantic and grammatical signals, and their pattern over extended sequences is fortuitous, rather than explicitly structured.

Whether pitch categorisation in music and language share any cognitive mechanisms is unknown. Indeed the issue is rarely, if ever, discussed in the literature. Yet there is neuropsychological evidence suggesting that the issue merits study. Specifically, a left-hemisphere bias has been found for the processing of categorical pitch information in both music and language. In music, the evidence includes ear asymmetries in the use of pitch interval information (Peretz & Babaï, 1992; Peretz & Morais, 1987), and significantly enhanced neuroanatomical asymmetries in the area of the planum temporale in absolute pitch possessors (Schlaug, Jäncke, Huang, & Steinmetz, 1995). In tone languages, the evidence comes from aphasia, in which deficits of tone perception in aphasia are associated with left-hemisphere damage (Gandour & Dardarananda, 1983). Crucially, this is not a generalised consequence of brain damage, as right-hemisphere damage in tone-language speakers spares the perception and identification of linguistic tones (Hughes, Chan, & Su, 1983).

Furthermore, right-hemisphere damage can impair the perception of affective prosody and yet leave the perception of linguistic tones intact (Hughes et al. 1983).

Thus, there is an intriguing suggestion that discrete categories of pitch, whether serving linguistic or musical functions, are especially reliant on left-hemisphere circuits. However, as noted above, differences between musical and linguistic pitch categories (notably, the presence of scales in the former) suggest that these two forms of pitch may be processed separately within the left hemisphere. The cognitive relation between music and language in this area awaits exploration.

TONALITY

"Tonality" can be defined as "a system of organising pitch in which a single pitch (the *tonic*) is made central." (Randel, 1978). Tonality has been a prominent aspect of Western European art and popular music, and rests on several structural features. Octaves are divided into twelve discrete pitches, separated by logarithmically equal steps, creating a system of 12 *pitch classes* (named a,a#,b,c,...g#). Subsets of this group of pitch classes form the scales and chords of tonal music, which are organised in compositions in such a way that at most points in the music there is structurally most central pitch class and chord (the tonic, and tonic triad, respectively), with other pitch classes and chords forming a hierarchy of structural importance in relation to these. In addition, shifts from one subset of pitch classes to another (modulation) are not random, but follow a particular logic of key relatedness (see Piston, 1978 for more details). These compositional regularities become internalised by listeners as "tonal schemata" or "tonal knowledge", which in turn influence the perception of music. Empirical evidence for the reality of tonal knowledge has been provided by a variety of perceptual studies (Krumhansl 1990).

Tonality has a fundamental role in the dynamic and expressive qualities of music. Different pitches and chords, via their network of structural relations in a musical context, take on the ability to imply continuation or closure, movement or rest. These perceptions are part of the dynamic experience of music (Bigand, 1993; Francès, 1988; Meyer, 1956; Narmour, 1991b; Schmuckler, 1989; Schumckler & Boltz, 1994). Furthermore, tonal schemata appear to provide a basis for some of music's emotional power: Sloboda (1991) reports that appoggiaturas occurred significantly more often than chance in musical passages identified as "tear-evoking" by subjects. An appoggiatura is a tone on an emphasised beat which forms a dissonance with the prevailing harmony, before resolving to a "harmonically correct" note. This illustrates one of the interesting aspects of stable tonal schemata: they provide a background against which departures are salient, and thus can be used to aesthetic and emotional effect.

None of the principal features of tonality appear to be part of any other domain. Although tonality has been referred to as musical "syntax", attempts to find deep parallels to linguistic syntax (e.g. Bernstein, 1976) have foundered on the fundamentally different structural categories of tonal versus linguistic grammar (Keiler, 1978). Tonal and linguistic syntax can be compared at a very general level: both involve orderly structural relations, embodied in the implicit knowledge of an experienced listener. However, we are not aware of any convincing evidence for structural overlap at more detailed levels. On the contrary, there is good evidence for considering the tonal encoding of pitch as specific to music (Balzano, 1982; see Peretz & Morais, 1989, for a more complete treatment of this issue; Shepard, 1982; Sloboda, 1985). There are serious indications that translation of pitch onto tonal scales is subserved by a modular system in Fodor's (1983) sense. This system seems to operate mandatorily and to be cognitively impenetrable (Shepard & Jordan, 1984); it corresponds to an early ontogenic development (see Trehub et al. this volume) and, above all, appears associated with neural specialisation (Peretz, 1993).

The critical neuropsychological property of a modular system is its potential to exhibit selective breakdown after brain damage. Recently, we had the opportunity to document a detailed analysis of a single case, G.L., who showed a true disturbance in tonal interpretation of pitch, as opposed to difficulties from other sources (such as an impairment in short term memory, contour or interval processing and comprehension of speech). Interestingly, at the time of testing, G.L. was no longer experiencing language difficulties (Peretz et al. 1994). For instance, G.L. obtained a normal score on the Token test (DeRenzi & Faglioni, 1978), which is considered to be a sensitive measure of phonological, syntactic and semantic aspects of spoken language comprehension.

In five different experimental settings, involving judgements of melodic closure, discrimination abilities and preferences, G.L.'s results converged on a lack of sensitivity to tonal melodic cues. This absence of tonal sensitivity stood in sharp contrast with his consistent and recurrent reliance on contour and, to some extent, on interval cues for performing the same tasks (Peretz, 1993). In this respect, G.L. represents the reverse dissociation of that reported earlier by Tramo, Bharucha & Musiek (1990). These authors described a patient who also suffered from bilateral brain damage but who could still use tonal knowledge despite severely degraded pitch discrimination abilities. This patient and G.L., when considered together, constitute a double dissociation for the encoding of pitch intervals and of tonal pitch. This should, however, be taken cautiously, for the two patients were tested with different procedures. Nevertheless, the available data argue in favour of the existence of a tonal module which is dedicated to music. As such, tonal encoding of pitch does not constitute a good candidate for probing shared processes between music and speech.

RHYTHM

There is no universally accepted definition of rhythm, yet rhythmic organisation is acknowledged as an essential feature of both music (Gabrielsson, 1993) and language (Cutler, 1991; Lehiste, 1991). To avoid confusion, we adopt the following definition for the discussion below: "rhythm" means the temporal and accentual patterning of sound ("accentual" means "perceptually salient in some way"). While rhythm has many aspects, we will only treat three of its subsidiary concepts here: *tempo*, which refers to the rate of events, *grouping*, referring to the clustering of adjacent elements into larger units, and *metre*, referring to a periodic temporal-accentual scheme. In music, grouping boundaries, which are influenced by melodic and harmonic structure, are not predictable from the metrical scheme. In other words, metre and grouping are separate, though interacting, aspects of rhythm (see Lerdahl & Jackendoff, 1983, for one discussion of this issue). Thus, we will treat grouping and metre separately with regard to their specificity (or lack thereof) to music.

TEMPO

In music, dynamic modulation of rate can have a significant role in musical communication: Gabrielsson (1987) documents a systematic pattern of speeding up and slowing down to mark melodic phrases in piano performance. In speech, modulation of rate can serve multiple functions, from the communication of emotion (Murray & Arnott, 1993) to pragmatic purposes such as avoiding interruption via increases in rate (Schegloff, 1982). The control of rate would appear to be a good candidate for processing overlap between language and music.

To our knowledge, the relationship between the control of tempo in music and speech has not been investigated, but is amenable to neuropsychological investigation. Specifically, subjects with disorders of speech rate due to neurologic damage can be tested for their ability to modulate tempo in non-verbal musical tasks. However, one caveat must be observed. Abnormal speech rate characterised by *slowing* may be secondary to a disorder of articulation or speech planning (Kent & Rosenbek, 1982; Rosenbek, Kent, & La Pointe, 1984), rather than a problem with the control of tempo *per se*. Thus it is more promising to study neurologic subjects with abnormally *fast* speech (tachylalia), where the tempo problem is less likely to be secondary in nature. Tachylalia is a rare symptom which has been observed in conjunction with different neurologic syndromes (Dordain, Chevrie-Muller, & Guidet, 1978), but its relation to non-verbal timing skills awaits investigation.

GROUPING

In both performance and perception, musical elements tend to be grouped into larger units, which may be informally referred to as "phrases" (the term is used somewhat variably between researchers). One notable feature of phrasing in both music performance (Gabrielsson, 1987; Repp, 1992a; Shaffer & Todd, 1987; Todd, 1985) and perception (Repp, 1992b) is that ends of phrases appear to be associated with slowing, or ritardando, with the degree of slowing reflecting the structural importance of the phrase boundary. This fact, combined with explicit representations of grouping structure and a metric for relating ritardando to boundary strength, has been used to model phrasal timing patterns in actual piano performances with reasonable success (Todd, 1985, 1989).

Grouping of elements in production and perception appears to be an important part of speech as well. Research on read speech in English has revealed that boundaries between groups of words are often marked by local slowing, called "preboundary lengthening", with the degree of lengthening significantly related to the extent of the subjective decoupling between groups (Wightman, Shattuck-Hufnagel, Ostendorf, & Price, 1992). The similar nature of constituent marking in speech and music has been noted by researchers involved in speech and music synthesis (Carlson, Friberg, Frydén, Granström, & Sundberg, 1989), though they caution that preboundary lengthening is not a linguistic universal. In fact, other mechanisms exist for marking boundaries in speech (Wightman & Ostendorf, 1994) and in music.

Given the empirical similarities between grouping in music and language, the possibility of shared cognitive mechanisms would be interesting to pursue. Some data from our study of amusic subjects CN and IR addresses this issue. Our study included 10 sentence pairs in which a change in timing pattern created a difference in meaning (e.g. Henri, le petit mange beaucoup./ Henri, le petit, mange beaucoup. Henry, the child eats a lot./ Henry, the child, eats a lot). For each of these "timing-shift" pairs, the durational characteristics of syllables was used to create a pair of rhythmic patterns (tone sequences with no frequency variation). These rhythmic patterns did not conform to any metric scheme, but reflected the temporal patterning of the original sentences, which grouped their syllables differently according to the meaning of the sentence.

The sentence pairs and rhythmic pairs were presented separately for same/different discrimination (pairs could appear in either configuration, and replicates were included). The results for CN, IR, and 8 controls can be seen in Figure 10.1. The Fisher exact probability test revealed that the level of performance across domains was not significantly different for either subjects or controls. IR was at chance in discriminating the timing-shift sentences as well as their rhythmic analogues. Her performance cannot be attributed to a general consequence of brain damage, as CN did quite well at this task (CN's performance was not significantly different from controls). Thus the pattern of results is consistent with some common mechanisms for grouping in language and music, though clearly more work is needed.

METRE

Metrical organisation is a prominent feature of musical traditions in diverse cultures: periodic temporal-accentual structures occur in the xylophone music of Zaire (Merriam, 1982), the tabla drumming of northern India (Kippen, 1988), and in many other traditions. In Western European music, metrical organisation tends to follow patterns based on multiples of two or three beats, with roughly even timing between those beats. Psychological investigations with westerners have confirmed the relevance of such metrical schemes in perception and performance (Clarke, 1985; Lee, 1991; Palmer & Krumhansl, 1990; Sloboda, 1983). One notable feature of recent theoretical treatments of metre in Western music has been the notion of a hierarchy of beat strength, with equal timing between beats at different levels of the metrical hierarchy (Lerdahl & Jackendoff, 1983).

A metrical scheme, once established, tends to create a stable pattern in the mind of the performer or listener. This in turn allows for meaningful deviations, such as syncopation, in which salient musical events occur on metrically weak positions. Syncopation illustrates the crucial fact that metrical patterns have a psychological reality apart from phenomenal accentual patterns.

The idea that metrical patterns are relevant to linguistic organisation has inspired both empirical and theoretical research. The notion of periodicity in speech production was formalised by Pike (1945) and Abercrombie (1967), who proposed that certain languages, such as English, produce stresses at roughly equal temporal intervals ("stress" is inconsistently defined in the speech literature: here we mean perceptual prominence, signalled by duration, intensity, pitch, vowel quality, or some combination of these). These "stress-timed" languages were contrasted with "syllable-timed" languages, such as French, which produce syllables at roughly equal intervals. Empirical research has not supported this notion (Roach, 1982). Rather, it has been suggested by Dauer (1983) that the temporal differences between these categories reflect different patterns of vowel reduction, syllable structure, and other phonetic and phonological factors. Dauer also provides data showing a general tendency to separate stresses in *both* "stress-timed" and "syllable-timed" languages, as well as in "unclassified" languages. Why so many languages should have this tendency is not conclusively known, although facilitating articulation may be one reason.

Although phonetics has not provided evidence for metrical patterning in ordinary speech, several theoretical treatments of linguistic rhythm have abandoned any concern with timing per se and focused on the patterning of

syllabic stress in spoken utterances. Theories of stress patterning have shared two notable features with theories of musical metre: hierarchical patterns of "metrical weight" (stress), and a tendency to alternate between stronger and weaker "beats" (syllables) (e.g. Liberman & Prince, 1977; Martin, 1972). Some of the earlier work in this area posited a quasi-metrical scheme for speech in order to derive observed stress patterns (Hayes, 1984; Selkirk, 1984). However, subsequent work, examining a greater variety of languages, has shown that a theoretical system based mainly on *avoiding* strong stress adjacency is likely to have more explanatory and predictive power than one founded on metrical principles (Nespor & Vogel, 1989). Congruent with this idea, a tendency to avoid stress "clashes" has been documented empirically for English (Shattuck-Hufnagel, Ostendorf, & Ross, 1994).

Thus, the "metricality" of language can probably be considered a result of a primarily negative tendency (avoidance of juxtaposed stress), whereas musical metre represents the active shaping of sound based on an underlying temporal-accentual scheme. An intuitive appreciation for this difference can be gained by considering the lack of a possibility for syncopation in speech. Before considering metre as an inherent difference between language and music, however, it is important to note that metrical organisation is neither universal in music, nor particular to it. Many European folk ballads (Seeger, 1966) and contemporary musical works lack significant metrical organisation, as do certain styles of North Indian classical instrumental music: similar examples from other traditions could doubtless be found. On the other hand, many forms of communication outside music can have quite regular metrical organisation, including some forms of poetic verse (Gross, 1979; Lerdahl & Halle, 1991). This suggests that metre is not an inherent property of any communicative domain, but an organisational principle which is optionally applied across domains (e.g. in music, language, dance, etc.). This in turn suggests that if processes subserving metrical organisation are disrupted, any behaviour relying on such processes should be disrupted, whether the behaviour is musical, linguistic, both, or neither.

In order to treat this question in a neuropsychological perspective, one needs first to demonstrate that metric organisation can be selectively disrupted after brain damage. The question of generalisation across domains can then be addressed in a meaningful way. Evidence for dissociating metre from rhythm has been found in a study where perceptual aspects of temporal processing were assessed (Peretz, 1990). In that study, two tasks were used: a standard "same-vs.-different" classification task and a "waltz-vs.-march" decision task. In the former, subjects were induced to rely on rhythm, for this was the only cue available for discrimination. In the other task, a "waltz-vs.-march" interpretation for each musical excerpt was used to promote metrical organisation, for it might be close to what listeners do implicitly when hearing the first bars of a musical piece in order to get ready for dancing. Both patient groups (left or right hemisphere lesion) were found to be impaired on the rhythmic task (as in Reitan & Wolfson, 1989). However, the metric test was successfully accomplished by most patients. The fact that metre judgement was spared in presence of disrupted rhythmic discrimination suggests that meter is not only distinct but also is not derived from rhythmic organisation.

The empirical evidence for generalisation of metrical processes across domains is scarce. There are, however, a few interesting suggestions. Cross-modal disruption of temporal processing (affecting both rhythm and metre, in both perception and production) has been described by Mavlov (1980) in a professional musician who sustained a lesion in the left posterior parietal hemisphere. The loss of rhythmic abilities in this patient affected temporal pattern reproduction regardless of whether the stimuli were presented in the auditory, visual or tactile modality. The patient's linguistic abilities were described as having returned to normal, though no mention was made of the temporal aspect of his speech. In contrast, Fries & Swihart (1990) describe an amateur musician who could no longer tap along in beat with a metronome or with music but who was still able to reproduce rhythmic patterns after having sustained a stroke in the right temporal lobe and the right basal ganglia (the patient was a left-hander). The deficit was modality specific in being restricted to audition. However, the metre deficit was described as affecting most motor behaviours, including articulation and speech rate. Although no systematic effort was made to compare performance on analogous musical and linguistic material, this study provides the first hint for the existence of a common mechanism governing metrical organisation in both domains.

SONG

Song is a universal form of auditory expression in which music and speech are intrinsically related. Song thus represents an ideal case for assessing the separability or commonality of music and language. Although songs may be created independently by two artists, the composer and the poet (or librettist), the two usually work in concert to integrate their respective contributions. For example, Palmer & Kelly (1992) have shown that linguistic prosodic structure and musical metre are generally aligned in Western art song, although these factors have independent effects on sung syllable durations, suggesting that they contribute separately to song performance. In memory, however, melody and text appear inseparable (Morrongiello & Roes, 1990; Serafine, Crowder, & Repp, 1984; Serafine, Davidson, Crowder, & Repp, 1986; Samson & Zatorre, 1991; but see Crowder, Serafine, & Repp, 1990 who admit the possibility of independent representations). In song memory, the musical and the linguistic component may be represented in some combined or common code.

Empirical evidence for this idea relies on the use of a memory recognition paradigm where novel songs are first studied and then presented with a forced-choice procedure. Subjects are required to recognise the melody, the lyrics, or both, of the songs that they had previously heard: among the alternatives are excerpts in which the melody of one song and the lyrics of another song are combined (mismatch songs). Integration effects are revealed by the systematic superiority of recognition scores for match songs over mismatch songs. Listeners behave as though they cannot access the melody without having access to the text, and vice-versa, of the studied song. This is a recurrent finding, which has been documented in normal adults (Serafine et al. 1984, 1986; Crowder et al. 1990), in preschool children (Morrongiello & Roes, 1990) and in epileptic patients after unilateral temporal lobe resections (Samson & Zatorre, 1991).

It should be pointed out, however, that all these data are derived from the use of the same paradigm. Thus, it is plausible that the integration effects are task-bound or material-specific. Given unfamiliar, interfering material among the response choices, subjects may form integrated representations of melody and text in memory in order to facilitate recognition. Such a strategy might not be efficient for the recognition of well-known songs, which are typically built around a few melodic lines, each of which can carry different lyrics. Consequently, encoding melody and text independently in normal situations might be more parsimonious and efficient. There is a particular need here for both diversity in experimental tasks and systematic neuropsychological investigations before we can draw any firm conclusions about the relation of musical and linguistic mental codes in song.

There are studies in the available neuropsychological literature that do suggest separability between melody and text. However, none can yet be considered conclusive. The first suggestion comes from an earlier study done by Goodglass & Calderon (1977) who obtained opposite laterality effects (and by inference opposite cerebral hemispheric superiorities) in the recall of musical and linguistic content of the same sung digits. The evidence relied on musicians only: thus, separability between melody and digits could be the product of a highly flexible and trained auditory system. The second suggestion comes from the dissociated behaviour of our amusic patients (notably CN) who is able to quickly and accurately recognise the lyrics of familiar tunes even though she is unable to recognise the corresponding melody (Peretz et al. 1994). Yet this dissociated behaviour is compatible with an interpretation of integration. CN's intact language system may be able to compute a correct sentence representation which can achieve contact with the stored song representation, while the impaired music system may no longer do so. The stored song representation may still correspond to a single entity where melody and text are integrated. To demonstrate separability, we need to (1) combine music and lyrics in songs (and not assess each component separately as in Peretz et al., 1994) and (2) obtain evidence of a double dissociation; that is, not only evidence for the selective loss of the music but also for the text. Such work is being actively pursued by the second author.

Finally, it should be noted that subjects with non-fluent aphasia have been known to sing the melodies (and sometimes the words) of previously learned songs, a phenomenon that has been documented for over 200 years (Dalin, 1736, cited in Benton & Joynt, 1960). However, the significance of this behaviour to the relation of melody and text representation in the brain is not clear. Studies of aphasic singing have been primarily descriptive (e.g. Yamadori, Osumi, Masuhara, & Okubo, 1977). One group has developed a speech therapy for aphasics based on melodically-intoned sentences (Albert, Sparks, & Helm, 1973, Helm-Estabrooks & Albert, 1991), but systematic research into the cognitive basis of aphasic singing has yet to be done. Another source of data on text and tune processing may be Alzheimer's disease, where intriguing hints of dissociations of memory for words and melody of songs have been reported (e.g. Swartz, Hantz, Crummer, Walton, & Frisina, 1989). Further research with both aphasic and Alzheimer's subjects could help elucidate the relation between linguistic and musical representation in memory.

CONCLUSION

The evidence reviewed in this chapter suggests that "music" and "language" are not independent mental faculties, but labels for complex sets of processes, some of which are shared and some different. Neuropsychology allows the empirical delineation of the boundaries between these domains, as well an exploration of their overlap. Accordingly, such research helps define the boundaries of "modularity" in language and music (Fodor, 1983; Gardner, 1983; Jackendoff 1987). For example, neuropsychological evidence suggests that the processing of pitch contour employs some of the same neural resources in music and language, while the processing of tonality appears to draw on resources used uniquely by music.

Numerous other areas of convergence and divergence between music and language await more thorough investigation. One benefit of such studies is a refined understanding of the functional and neural architecture of both domains. More generally, studying language and music in parallel offers a chance to understand human auditory communication and cognition in a broader perspective than is possible by studying either domain alone.

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