Chapter 8

The Perception of Musicality

The starting point of my newer theory of music, which is the main theory developed in this book, is the assumption that music itself has no purpose, but that our *response* to music has a purpose. Music is a **super-stimulus** for the perception of **musicality**, and musicality is a perceived attribute of *speech*.

All of the cortical maps that respond to music are actually cortical maps whose purpose is to respond to speech. Every aspect of music corresponds in some way to an aspect of speech perception, although the nature of this correspondence may not always be obvious.

8.1 Where is the Purpose?

We have already asked the question: What is the biological purpose of music? But biological purpose only exists within the structure and behaviour of living organisms. Music is not a living organism; the living organism in this case is the human being who enjoys music. Music only exists as a result of human behaviour in relation to music. The most significant human behaviours that relate to music are:

- Composing music
- Performing music
- Listening to music

- Dancing to music

In which of these resides the true biological purpose of music? Is it in composition, where the composer creates music in order to express their emotions, or communicate in some way with the listener? Or is it the performance of music, where the performer expresses and communicates? Is there something special about the group performance of music, which bonds the members of society together as they perform together? Is it dancing, another group activity, with bonding and good exercise thrown in as an extra? Is it just the listening that does something useful, letting us understand the emotions of the composer and performer?

8.2 That Which is Like Music

Perhaps we are assuming too much when we list the choices above. Maybe the biological purpose associated with music is not actually about the music. Is this possible? Could the biology of music actually be about something else?

A simple question follows from this line of thought:

> What is the thing that is most like music which is *not* music?

We can try to answer this question by looking at different aspects of music. These include at least the following:

- Melody
- Scales
- Rhythm
- Harmony
- Chords
- Home notes and home chords
- Bass
- Instrumental timbres with harmonic frequencies that are integral multiples of the fundamental frequency
- Repetitions: exact and partial, free and non-free
- Rhyme

As it happens, there exists one very important human behaviour that has at least three of these aspects, and that important behaviour is *speech*. The three aspects that speech has in common with music are melody, rhythm and timbres with harmonic frequencies that are integral multiples of the fundamental frequency.

Speech has melody, because the pitch of the voiced portions of speech goes up and down as the speaker speaks. This "speech melody" can include—depending on the language—**lexical pitch**, **pitch accent** and **intonation**. Languages that use lexical pitch, where each individual word has its own little melody, are called **tone languages**; one well-known example is Cantonese. Pitch accent is where the accents of words are partly defined by changes in pitch; typically a rise in pitch represents an accent. Intonation is where a sentence or phrase has an overall melodic shape that says something about the meaning, intention or emotion associated with that sentence or phrase. (Classifications of languages into those that do or do not contain pitch accent and/or intonation are not absolute. Some languages indicate accent almost entirely by pitch, such as Swedish; in other languages it forms part of the indication of accent, as in English. And there is often variability in the occurrence of pitch accent across different dialects of one language. Intonation occurs in many languages, more so in those languages that do not have lexical pitch.)

Speech also has rhythm. We can define rhythm as the patterns of timings of syllables in words. Each language has its own typical patterns of rhythm. This rhythm plays a significant role in the perception of language: in particular it helps to predict the locations of syllable boundaries. If you have ever tried to write speech recognition software, you'll know that syllable boundaries are more difficult to spot than one might suppose. And it's rather hard to identify the content of syllables if you are not even too sure of where they start and end. One of the ways that our brains can solve this problem is to use the observed times of previous syllable boundaries to predict the likely times of future syllable boundaries. The known properties of a language's rhythms are what make this prediction possible. It has been established that babies become sensitive to the rhythms of the language spoken around them at quite an early age.

And finally, the spoken human voice has an instrumental timbre with harmonic frequencies that are integral multiples of the fundamental frequency. (To be precise, it has these qualities when it is uttering **voiced** sounds, i.e. vowels and voiced consonants.)

This is not by any means a complete match between the aspects of speech and the aspects of music, at least not with regard to those aspects that are obvious to us. But it does appear that speech is closer to music than anything else is.

We could consider poetry as another candidate for something which is "like music but which is not music". Poetry has a regular rhythm, and it has rhyme. Poetry can be seen as something that lies in between ordinary speech and music in its characteristics. However, in the general scheme of things, poetry is less significant than either speech or music. By any simple economic measure, the amount of time, money and effort that the general population puts into the production and consumption of poetry is far less than what they put into the production and consumption of either speech or music. And poetry does not have any obvious biological purpose any more than music does. So, for the moment, we will ignore poetry. And later we will see that the theory we develop enables us to formulate a more abstract definition of music, such that poetry turns out to be a minor form of music in itself.

Having "matched" music with speech, we should mention the obvious discrepancies, both in what we matched and in what we did not match:

- A melody can be defined as pitch which is a function of time. In speech melody, pitch is generally a continuously varying function of time, whereas in musical melodies pitch is constant for the duration of a note, and then jumps suddenly to the pitch of the next note. Also the pitch values in a musical melody take on only a finite set of values corresponding to the notes in a scale. There are no scales in speech.
- Speech does not have harmony or chords, unless perhaps we consider several people talking at once. And if there are no chords, then there are definitely no home chords.
- The rhythm of speech is not regular in the way that musical rhythm is regular. There is no regular hierarchical division of time as there is in music.
- Speech does not have a bass accompaniment.
- Exact repetitions of phrases or sentences do not normally occur in speech.
- Ordinary speech does not rhyme.

The only match that appears without any caveat or discrepancy is the match between the spoken human voice and the human voice as a musical instrument; in fact the human voice is the most popular musical instrument, as most popular music is in the form of song.

There are also many aspects of speech that have no obvious equivalent in music, including vocabulary, syntax and semantics (although some authors have tried to draw analogies with these aspects of language).

One day I was thinking along these lines, of how music resembles speech and that in some ways music seems almost like a parody of speech, and I had an idea. My flash of inspiration was this: there is a somewhat limited match between speech and music, but maybe the real match isn't between speech and music *per se*, maybe the real match is between the *perception* of speech and the *perception* of music. Maybe there is a match between the cortical maps that respond to speech and those that respond to music.

Now the main result of perceiving music appears to be the perception of the **musicality**[1] of music, which causes a pleasurable emotional effect. The main result of perceiving speech is understanding the semantics of what is being said. But that is not the only result of perceiving speech. There are other things that we perceive, like the identity of the speaker, and the emotion of the speaker, and clues as to whether the speaker is being honest with us. So if speech perception includes these various extra perceptions, maybe *the perception of musicality is yet another aspect of speech perception.*

In other words, musicality is an attribute of speech, which provides the listener with some significant information about speech. (Musicality is assumed to be significant, whether or not we think we know what that significance actually is. But we will make hypotheses about that as well—later on.)

But if musicality is an attribute of speech, what then is music? Music is a *contrived stimulus* or **super-stimulus**, which is contrived so as to have a high level of musicality.

This idea of a super-stimulus is well known in the field of biology. Ethologists are fond of taking apart the ways some animals respond to their environment, and discovering super-stimuli that create a more extreme response in the animal than the normal stimuli.

Some well-known super-stimuli have been discovered by scientists studying the feeding of baby birds by their parents. In fact super-stimuli have been discovered for both parent and chick behaviour: artificial parents that the chicks prefer to beg food from, and artificial chicks that the parents prefer to feed. The super-stimuli are often just over-simplified models of the parent or child bird, generally with exaggerated versions of markings that have been observed to play a role in the begging or feeding reflexes in question.

An example is given by Professor Vilayanur Ramachandran in his 2003 Reith Lecture (on BBC Radio).[2] He refers to work done by the ethologist Niko Tinbergen on herring gulls. The chick's begging reflex is tied to the colour pattern on its parent's beak, which is yellow with a red spot. The chicks will beg from a beak that has been separated from its owner, and they will beg even more enthusiastically from a long yellow stick with three red stripes on it. This coloured stick is the super-stimulus.

Ultimately the real beak and the super-stimulus beak must create a response in the same cortical (or maybe non-cortical) map in the baby gull's brain. The nature of the super-stimulus tells us something about what that particular cortical map responds to.

[1] The word "musicality" has at least two common meanings: firstly describing how musical a *person* is, and secondly describing how musical some *music* is. It is the second meaning of the word that is used throughout this book.

[2] Also published as a book: *The Emerging Mind* (Profile Books 2003).

The purpose of Professor Ramachandran's lecture was to explain his theory of human art based on various principles that could be derived from our scientific understanding of how the brain works—and one of those principles was that of the super-stimulus.

If music is a super-stimulus, then it is certainly a more complex super-stimulus than a yellow stick with three red stripes. Although popular music may be simpler than classical music, and some popular music is very simple compared even to other popular music, there is still a minimum level of complexity. There are also many distinct items of music: all those that have ever been composed, and probably an even larger number that have not yet been composed. And music has various different aspects: melody, rhythm, harmony, bass, home chords etc.

These complexities of music suggest, although they do not absolutely prove, that the perception for which music is a super-stimulus is one that has a moderately level of complexity in itself. The human cortical maps involved in the perception of musicality probably perform information processing much more complex than that which is performed by the cortical map in the herring gull chick's brain that responds to the yellow and red pattern of its parent's beak.

8.3 Corollaries to the Hypothesis

Firstly I will restate the hypothesis as developed so far:

- The perception of musicality is an aspect of speech perception.
- The perceived musicality of speech represents useful information about the speech being listened to. The benefits of perceiving this information have provided the selective pressure that has driven the evolution of the ability to perceive musicality.
- Music is a contrived super-stimulus, contrived so as to have a high degree of musicality.

This hypothesis explains at least some of the properties of music in relation to speech, and it explains why music is not exactly like speech. And it fits plausibly into the framework of Darwin's theory of evolution by natural selection.

But at the same time it gives rise to a whole range of new questions:

- What is musicality? Or more specifically, what information does musicality provide about speech? And how does that relate to the emotional effect of music?
- Is musicality a one-dimensional attribute of music? That is, does it reduce to a simple "this music has low musicality", and "that music has high musicality"?

- Why is it not subjectively obvious to us that musicality is a perceived feature of speech?
- There are claims in the scientific literature that there is **double dissociation** (a term that I will explain when I attempt to answer this question) between music perception and speech perception: does the evidence supporting this claim contradict the musicality hypothesis?
- For the aspects of melody and rhythm, how do we explain the differences between speech melody and musical melody, and between speech rhythm and musical rhythm?
- What about other attributes of music that appear not to exist in normal speech at all, i.e. scales, harmony, home notes, home chords, bass and rhyme?
- What does the hypothesis tell us about the cortical maps that respond to music and speech? Can the aspects of music help us understand the nature of the cortical maps involved in speech perception?

These are not all the questions that need to be answered. An investigation of musical symmetries and invariances raises more questions. Symmetries turn out to be so important that I devote a whole chapter to listing and describing the full set of symmetries of music perception.

8.3.1 What is Musicality?

What is musicality? Or more specifically, what information does musicality provide about speech? And how does that relate to the emotional effect of music?

The first thing to say is that the musicality hypothesis, i.e. the hypothesis that perception of musicality is an aspect of speech perception, was enough to lead me on a long path of successful investigation into the mechanics of music perception. I found out a lot of things about music, *without even knowing what musicality was or what information it represented*. In the end, I was able to come up with a plausible answer to this question: musicality represents an estimate of a certain aspect of mental state of the speaker, corresponding roughly to **conscious arousal**. But I remain more confident of the general musicality hypothesis than of my more specific theory as to what musicality actually is.

The theory of **constant activity patterns** (or **CAP**) is fully explained in Chapter 14. It tells us that musicality is caused by the occurrence of activity patterns in neural maps that remain constant, and that the means by which the listener's brain calculates musicality represents an attempt to detect the occurrence of similar activity patterns in corresponding neural maps in the *speaker's* brain, which provides information about the speaker's level of conscious arousal, which in turn influences the listener's perception of the speech content and in particular influences their emotional reaction to that content.

Before we can get to the details of the CAP theory, we need to investigate and understand musical symmetries and cortical maps, so for the moment it is best to defer consideration of the meaning of musicality, and just continue under the assumptions that (1) there is such a thing as musicality and (2) the perception of it is something that matters.

8.3.2 The Dimensionality of Musicality

Is musicality a one-dimensional attribute of music? That is, does it reduce to a simple "this music has low musicality", and "that music has high musicality"?

On the one hand, the musical quality of music does seem to be multi-dimensional, in that different types of music evoke different emotions and different feelings. On the other hand, the musicality-arousal hypothesis suggests that there is one primary dimension to musicality, which determines the music's ability to evoke an emotional response. Furthermore, the musicality-arousal hypothesis states that an emotional response is only *supported* by the musicality, and if any specific emotion is evoked, it must be evoked by some other aspect of the music.

One of the most often asked questions about music and emotion is: why do minor chords sound "sad" and major chords sound "happy"? The theory in this book, unfortunately, does not have much to say about this issue. But if musicality is a one-dimensional attribute, then this implies that the *quality* of emotion evoked by a tune—if there is a definite quality of emotion evoked by that tune—is independent of whatever it is that determines if a tune is very musical or not very musical. If a very musical tune has mainly minor chords it will evoke a strong feeling of sadness, and if a very musical tune has mainly major chords it will evoke a strong feeling of happiness. If a tune is not very musical, then it will evoke an emotion in accordance with the chord type, but the emotion evoked will be weaker on account of the tune's lower level of musicality.

8.3.3 Subjective Awareness of Musicality

Why is it not subjectively obvious to us that musicality is a perceived feature of speech?

According to the theory, music is a *super-stimulus*, meaning that the effect generated by music is much stronger than for normal speech. We are aware of the emotional effect of music, but we are not internally aware of the processes that generate that emotional effect. When musicality affects the perception of normal speech, it probably has a mild reinforcing effect on our emotional response to the content of the speech being perceived. The musicality of normal speech affects our emotional responses, in a subtle way, and it always has done, but without us realising it. The question "Why are we not consciously aware of this effect?" is a little bit like the question "How come we don't notice the centrifugal force caused by the Earth's rotation?". The answer to the latter question is that the gravity we feel is the gravity that would be there if the Earth wasn't rotating, minus the effect of the centrifugal force. We are not aware of the presence of the centrifugal force, because we have never experienced what it would be like to stand on an Earth that was not spinning. Similarly, we might become consciously aware of the effect that the perception of musicality has on our perception of speech if it was suddenly disabled in some way.

Another way of looking at this is to compare machine-generated speech to human speech. All man-made speech machines to date are not capable of accurately simulating normal speech, in as much as they do not sound completely natural to a human listener. The unnaturalness of artificial speech corresponds to various aspects missing from it. One of those missing aspects is the musicality of the speech, since no provision is made for musicality in the algorithms that generate the speech.

8.3.4 Double Dissociation

There are claims in the scientific literature that there is double dissociation between music perception and speech perception: does the evidence supporting this claim contradict the musicality hypothesis? (Some examples are given in *The Cognitive Neuroscience of Music*, John Brust "Music and the Neurologist: A Historical Perspective", and Isabelle Peretz "Brain Specialization For Music: New Evidence from Congenital Amusia".)

Double dissociation of two components of cognition A and B refers to finding subjects with disabilities, where one subject has A but not B, and another subject has B but not A. Double dissociation of music and speech refers to subjects who can perceive musical qualities of music but cannot understand speech, and subjects who can understand speech but cannot perceive the musical qualities of music. **Amusia** is a general term for loss of musical ability, and **aphasia** refers to loss of language perception or ability.

I can answer this question better when I consider the musicality-arousal hypothesis in more detail, but the following points can be noted:

- If our theory claims that music perception is a *subset* of speech perception, then only amusia without aphasia provides any challenge to the theory—aphasia without amusia is entirely possible since an aphasia may apply to an aspect of speech which is not an aspect of music.

- You cannot dissociate an aspect of music perception from speech perception if you don't know what music perception is perception of—you cannot dissociate two components of perception if at least one of them is unknown in function and purpose.

- Perception of musicality may only be relevant in some circumstances, i.e. when the speaker is aroused and the semantics of what they are saying has emotional consequences for the listener. (An alternative hypothesis is that the *emotional* effects of musicality only apply in some circumstances, but there may be other effects of musicality on our perception of speech that apply more generally, in which case amusia would affect those aspects of speech perception in all cases.)

Thus, in all likelihood, the subjects with comprehension of speech but lack of music perception *also lack those aspects of speech perception that depend on their ability to perceive musicality.* Since the scientific observers studying these subjects do not know what role the perception of musicality plays in speech perception, they will fail to observe that their subjects lack those aspects of speech perception.

8.3.5 Differences in Melody and Rhythm

For the aspects of melody and rhythm, how do we explain the differences between speech melody and musical melody, and between speech rhythm and musical rhythm?

There are two steps that connect "normal" stimuli to super-stimuli:

1. The requirements for perception of normal stimuli determine the structure and operation of the cortical maps that perform that perception.

2. The structure and operation of the cortical maps that perform a given perceptual task determine the nature of the super-stimuli for that perception.

A common consequence is that super-stimuli are qualitatively different to the corresponding normal stimuli.

We can consider this explanation even in relation to individual neurons. For example, perceptual neurons in the brain that encode for colour of light (not colour of objects) will have the strongest response to pure spectral colours. Such colours hardly ever occur in nature.[3] But the proper purpose of these neurons is not to perceive pure spectral colours: it is to perceive and distinguish all the other colours that occur naturally.

Hair cells in the organ of Corti respond maximally to pure sine tones at a particular frequency. Again such tones hardly ever occur in nature, and it

[3] Even rainbows are blurred. In my own personal experience, the nearest one gets to pure spectral colours in nature is when seeing small flashes of spectral colour from sunlight refracted through individual drops of dew in the grass.

is not the purpose of these hair cells to respond to pure tones; rather their purpose is to perceive sounds in general.

There is an interesting analogy between pure spectral colours and pure tones: both are pure regular sine wave vibrations at a particular frequency. It is quite commonly the case that super-stimuli for a perceptual sub-system are more regular in form than the ordinary stimuli that the perceptual sub-system is designed to respond to. This can explain some of the differences between music and speech. For example, the rhythms of music are much more regular than the corresponding rhythms of speech, but the purpose of neurons that respond strongly to regular rhythm may actually be the perception of *irregular* rhythms.

Similarly, we might speculate about the regular patterns of frequency that occur in musical melody versus the patterns that occur in speech melody. We will find, however, that properly solving the problem of musical scales versus smoothly varying speech melody requires a more in-depth understanding of the cortical maps underlying the perception of melody.

8.3.6 Attributes Apparently Absent in Speech

What about other attributes of music that appear not to exist in normal speech at all, i.e. harmony, home notes, home chords, bass and rhyme?

This question will—for each attribute—have a similar answer to the previous question. But for these aspects it is less obvious what the corresponding attributes of speech are. In the end we will find it easier to backtrack along the line of implication that goes:

$$\text{Perception of Ordinary Stimulus} \Rightarrow \text{Cortical Map} \Rightarrow \text{Super-Stimulus}$$

In other words, we will look at the aspects of music (the super-stimulus), and we will make an intelligent guess as to what types of cortical maps respond to those aspects, and then we will make further intelligent guesses as to how those cortical maps fit into the requirements of speech perception.

For a simple example, we can look at **harmony**. Harmony is multiple notes played together. We might suppose that this has something to do with multiple speakers speaking at the same time. But our brains do not normally attempt to comprehend more than one speaker at a time; indeed it is hard enough to fully perceive all relevant aspects of the speech of just one speaker. This difficulty can be solved if we distinguish the super-stimulus that activates a cortical map from the normal stimuli that are intended to activate it. In the case of harmony, we can suppose that there exists a cortical map that responds strongly to multiple pitch values separated by consonant intervals, but at the same time suppose that the purpose of that cortical map is to respond to just one pitch value at a time. One clue comes from observing how chords can be played: we can play all the notes of a chord at once, but we also get the effect of the chord by playing the notes of the chord in sequence. So we have proof that the cortical map that responds to multiple simultaneous pitch values can also respond to the same pitch values occurring sequentially.

Of course the actual purpose of this "harmonic/chordal" cortical map will not be to respond to distinct notes of *constant* pitch value separated by consonant intervals, because speech melody does not have this form. We will eventually develop a hypothesis that the purpose of this map is to calculate the durations between points in speech melody that differ by consonant intervals. These calculated durations give partial information about the "shape" of a melody (and in a way that happens to be **pitch translation invariant**, more of which in the next chapter).

8.3.7 Implications for Cortical Maps

What does the musicality perception hypothesis tell us about the cortical maps that respond to music and speech? Can the aspects of music help us understand the nature of the cortical maps involved in speech perception?

These questions have already been partly answered by my answers to the other questions: investigating the aspects of music will enable us to guess the nature of cortical maps that respond to those aspects, and then we will make further guesses as to the purpose of those maps in perceiving normal speech.

The musicality hypothesis will ultimately (see Chapter 14) allow us to place a stronger constraint on the relationship between responses of cortical maps to music and their responses to speech, which is:

> If the activity patterns of a cortical map contribute to determining musicality, then the primary purpose of that cortical map is *not* the perception of musicality, and in fact must be related to some other aspect of speech perception.

Roughly speaking, we can explain this by saying that musicality is a *secondary* aspect of a cortical map's activity, so there must be some other reason that the cortical map exists in the first place.

8.4 Explaining Musical Behaviours

I started this chapter with questions about the purpose of musical behaviours, but then went on to suggest that the real purpose lies within the *perception* of musicality. For the sake of completeness, we should verify that all musical behaviours can be explained this way.

One issue that comes up, when scientists investigate different musical cultures, is that in the more "traditional" (i.e. small tribal) cultures, there is a much greater degree of participation in musical activity. Almost everyone participates in structured musical performances. There may even be a greater involvement in the composition of music. If we compare this to modern Western culture, where many people's participation in music is to switch on the radio and listen, then Western culture seems to be the odd one out. Maybe any hypothesis about music should be based on the creation and performance of music, rather than the consumption of it, since the majority of cultures give greater emphasis to those aspects of music.

One can argue, however, that the differences between music creation and consumption in small tribes and in the modern Western world have to do with economics, technology and numbers. In the modern world we have easy and fairly cheap access to the best possible music, created and performed by experts who work full time on nothing else. A very small number of composers and performers can do all the work needed to make the music, and everyone else can just listen and enjoy. In a small tribe, if you want to hear good music, you are probably going to have to perform it yourself. So it can plausibly be argued that in both cases—traditional tribal society and modern technological civilisation—the driving force is the desire to *listen* to music.

Even if there are many people in Western society who occasionally perform to the best of their ability (singing not quite in tune in the shower, or singing "Happy Birthday" at a birthday party), most people do not find such performances very satisfying unless they can achieve something that also gives enjoyment to themselves as a listener. (Counter-argument: maybe Western culture—with its emphasis on not even trying to do something unless you can do it really well—artificially discourages the practice required to become musically competent, and in other cultures musical competence may be more commonplace.)

The modern musician may hope to make lots of money, or meet lots of attractive groupies, or just get kudos for being a great entertainer, but achieving all these things rests on their ability to please their audience, which rests on the audience's desire to listen to good music, i.e. music which has a high level of musicality.

Another type of behaviour that has been suggested as showing the purpose of music is behaviour as part of a group, i.e. performing or listening to music in a group.[4] We know, however, that musical performance and listening to music can both be enjoyed on a purely solitary basis, particularly as modern technology allows the listener to enjoy music without immediate involvement by any other person, and the performer can also perform without anyone else performing with them and without any listeners (other than themselves) directly listening to them. It is not clear that music has a social purpose any more than other activities such as eating, drinking or going for a walk in the countryside. Each of these activities occurs socially, but it is not necessarily the *purpose* of any of them to promote social bonding.

[4] As already mentioned in Section 3.4.1 (page 49).

8.4.1 Dance

There is also a relationship between dance and music: given the right type of music many people will enjoy dancing to it, and most dancing is accompanied by some kind of music. Perhaps the real purpose of music is to facilitate or encourage dancing. This of course raises the question as to what the biological purpose of dancing is. Dance can be good exercise, and it can be a social activity, and it also plays a role in sexual/romantic interactions between the sexes. But it is not at all clear why dance should be necessary to further any of these aims—they can all be achieved quite satisfactorily without it.

People also enjoy *watching* dance, and at least part of the reason that people dance is for the effect that it has on those watching. The musical theory that I develop in this book readily explains the multiple aspects of music—melody and rhythm etc.—and relates these aspects to the perception of an individual speaker speaking to the listener. Perception of a speaker speaking is more than just listening to the sounds made; it also involves watching the posture and movements of the speaker. It is entirely possible therefore that dance is a visual super-stimulus relating to the visual perception of movements made by a speaker. We can even incorporate dances involving multiple dancers into this theory, in the same way we incorporated harmony: the cortical map that responds strongly to watching multiple dancers dancing in synchrony has as its primary function the perception of the motion of *one* person.[5]

Including dance in the theory of musicality explains another fact about dance that we take for granted without realising it: there is no such thing as *non-human dancing*. We can make objects, pictures and animals move around to the music. This can look amusing or mildly interesting, but it lacks the emotional effect of watching human dancers dance.

One musical aspect of dance is its obvious relationship to rhythm: whether we dance or watch others dance, we prefer the rhythm of the dance movements to match the rhythm of the music.

Another possible musical aspect of dance, which I can only confirm from personal observation, is an apparent **stepped constancy of motion**. At any given point in time, we will have a general perception of how fast a dancer is moving their body. In some forms of modern dancing, one can observe a smoothness of motion with a subjectively constant speed, sometimes with sudden changes from one speed to another, where these changes are synchronised to the rhythm of the dance and the music. This can almost be interpreted as a form of legato, analogous to the legato of melody. In the melodic legato it is the pitch that steps from one constant value to another; in the dancing "legato" it is the subjectively perceived speed of motion that steps from one value to the next.

[5]Although the effect of dancer multiplicity may be more analogous to the "chorus" effect (which occurs when we hear multiple singers singing in unison, i.e. all singing the melody), than it is to the effect of harmony.