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CHAPTER 2

THE QUEST FOR UNIVERSALS IN TEMPORAL PROCESSING IN MUSIC

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One would ultimately hope to specify these cognitive principles or "universals" that underlie all musical listening, regardless of musical style or acculturation. To what extent is it learned, and to what extent is it due to an innate musical capacity or general cognitive capacity?

Lehrdal & Jackendoff[1]

Abstract

Music perception and performance rely heavily on temporal processing: for instance, each event must be situated in time in relation to surrounding events, and events must be grouped together in order to overcome memory constraints. The temporal structure of music varies considerably from one culture to another, and so it has often been supposed that the specific implementation of perceptual and cognitive temporal processes will differ as a function of an individual's cultural exposure and experience. In this paper we examine the alternative position that some temporal processes may be universal, in the sense that they function in a similar manner irrespective of an individual's cultural exposure and experience. We first review rhythm perception and production studies carried out with adult musicians, adult nonmusicians, children, and infants in order to identify temporal processes that appear to function in a similar fashion irrespective of age, acculturation, and musical training. This review leads to the identification of five temporal processes that we submit as candidates for the status of 'temporal universals'. For each process, we select the simplest and most representative experimental paradigm that has been used to date. This leads to a research proposal for future intercultural studies that could test the universal nature of these processes.

Keywords: Temporal processing; Rhythm perception; Segmentation; Grouping; Regularity; Duration ratios

Towards intercultural research in temporal processing

We plead guilty to the charge of cultural egocentricity. In previous research, we have proceeded as if the musical environment the world over is identical to that in France, Belgium, England, and the United States (the countries in which we have carried out our experiments). The musical environment in these countries is relatively homogenous in the sense that it is dominated by a Western tonal tradition (although we acknowledge significant differences even between these environments). From a rhythmic point of view, both our 'classical' and 'popular' musics are dominated by relatively simple rhythmic structures, organized around a regular beat, with binary or ternary multiplications and subdivisions of this beat.[1,2] By focusing on the auditory world around us, we have identified some of the psychological rhythmic processes that appear to function in our particular instance when listening to or producing 'our' type of music. Following the results of this developmental prospective, we have even made the claim that some of these processes function the same way whatever the musical environment in which a listener is immersed.[3] Despite this previous highly focused position, we are fully aware that our assumptions concerning the generalizability of these processes to other cultures are only that—assumptions. This paper is an attempt to make amends for our previous cultural egocentricity by suggesting how our psychological developmental prospective could be adapted to an intercultural one, into which existing knowledge from the field of ethnomusicology and future cross-cultural studies could be incorporated.

Our previous research has focused on how people hear musical and nonmusical rhythms in order to identify the underlying psychological processes that make the perception of music such a fulfilling and satisfying activity. Music is typical of all forms of sustained activity over time, in that it can be successfully perceived or performed only if the individual events from which it is composed are perceptually integrated into larger units spread over time. Indeed, music has been defined as the art of organizing events in time. As such, it provides an ideal opportunity to investigate the perceptual and cognitive temporal processes that make such activity possible.

In the past we have adopted the experimental principle of comparing performances on both perceptual and motor rhythmic tasks by people varying in levels of rhythmic skill, be it by age (as children get older there is a gradual increase in their exposure to, and experience with, the rhythmic structures around them) or musical training (the musical training common to our culture is particularly characterized by the development of explicit knowledge about musical structure). Such an experimental principle allows us to tease apart the processes that appear to be 'innate' or 'hard-wired' (functioning at birth, determined by genes, independent of environmental influence, and experience) and those that develop with maturation, acculturation (learning by immersion in the auditory world around us), or explicit training. The principle has been that if young infants, children, and nonmusician and musician adults display similar functioning modes on a particular task, then we conclude that this process may be 'innate' or at least 'functional' at an early age. Alternatively, if differences are observed between these populations, we then conclude that this type of functioning is acquired, either through acculturation or explicit learning.

We have, in the past avoided the word *innate* due to strong theoretical and philosophical connotations, referring rather to processes that may be universal—that is, that function in the same way in everyone. However, as has been pointed out to us, this wording is ambiguous. If we claim that a process is universal, we must demonstrate that it occurs the world over, irrespective of the cultural environment in which the individual lives and grew up. The present paper proposes such a research project. Whereas we have the know-how about both the psychological processes involved and appropriate paradigms to demonstrate the functioning of these processes, we are quite ignorant of the enormously exciting field of ethnomusicology, and our attempts at contact have so far been limited. Such a project cannot be accomplished on our own, or even with just one or two colleagues, but requires numerous sites the world over with researchers collaborating within a network.

Temporal processing is limited by memory space and processing time

If a computer programmer wanted to make a computer reproduce a musical rhythm, the program would probably record the precise duration (in milliseconds or computer clicks) of each interval in the sequence, put them in a lookup table, and then recall these values to produce the rhythm. The result would be that the reproduced rhythmic structure would be identical to that of the model. Is this a good model for the functioning of the human perceptual system? Probably not. Whereas human beings are able to reproduce musical rhythms so that they sound satisfactorily similar to the model, previous research suggests that our perceptual system does not function in the same way as the computer. The main difference in the way computers and humans function concerns memory limitations: computer memory is usually not a problem, while human memory is severely limited. As psychologists, our task is thus to describe the way in which our perceptual system analyses incoming temporal information and how it overcomes the main enemies: memory space and processing time.

Sound events usually do not occur in isolation, but rather are surrounded by other events, with each sound embedded within a sequence. Each event takes its existence from its relation with these surrounding events, rather than from its own specific characteristics. The task of situating each event in relation to surrounding events is quite simple when the sequence is short in duration and when it contains a limited number of events (i.e. three or four intervals). However, as the sequence becomes longer we very quickly run into problems of memory space and processing time. Imagine the number of intervals that would need to be stored and accessed when listening to a Beethoven sonata!

The idea is that all events would be stored in a memory buffer lasting several seconds (psychological present, probably corresponding to echoic or working memory), allowing the system to extract all relevant information (interval duration). One can imagine a temporal window gliding gradually through time, with new events arriving at one end and old events disappearing at the other due to decay. Thus only events occurring within a span of a few seconds would be accessible for processing at any one time, and only events occurring within this limited time window can be situated in relation to each other by the coding of relevant relational information. However, when the sequence becomes more complicated (longer and/or more events), the number of events that must be processed quickly goes beyond the limits of this buffer. Consequently, simple concatenation models that propose the maintenance in memory of the characteristics of each event are not able to account for the perception of long sequences because of problems of memory overload.

In this chapter, we present a set of five temporal processes that overcome these constraints, at least partially. These processes have been selected because previous research in the field of rhythmic perception suggests that they function in a similar fashion in all the populations examined so far. They are therefore candidates for the status of 'temporal universal'. This is not an exhaustive list, and other candidates could certainly be added as the project advances. As mentioned above, this list emerges from previous developmental and comparative studies. In each case we select key paradigms that we have used successfully in the past to demonstrate the lack of difference between populations differing in age and musical experience. An essential characteristic of developmental research is that the tasks used must be conceptually simple; must not require reading, writing, or any other specific knowledge such as musical notation; must be short (usually not more than 20 min of experimenting time); and must be technically transportable (into schools). As such, the paradigms we have used for children should be easily adaptable for intercultural research, which faces similar constraints. Taken together, this set of experimental paradigms could be used as a basis for answering the question of the true 'universal' nature of these psychological processes.

Candidate 1: segmentation and grouping

We tend to group into perceptual units events that have similar physical characteristics or that occur close in time.

One way to overcome processing limitations and to allow events to be processed together is to group the events into small perceptual units. These units result from a comparison process that compares incoming events with events that are already present in memory. If a new event is similar to those that are already present, it will be assimilated. If the new event differs too much (by its acoustical and/or temporal characteristics), the sequence will be segmented. This segmentation leads to the closure of one unit and the opening of the next. Elements grouped together will be processed together within a single perceptual unit and thus can be situated in relation to each other.

Several studies support these ideas. Listeners usually segment sequences as a function of the surface characteristics (timbre, pitch, intensity, event duration, pauses, etc.), following the principles laid down by the Gestalt psychologists: a change in any sound parameter leads to the perception of a break in the sequence and thus to the creation of groups separated by the changes (see Ref. 5 for a summary). For instance, the occurrence of a longer temporal gap or a major change in pitch leads to the segmentation of the sequence at that point, with the termination of one perceptual unit and the beginning of the next.

Paradigm 1: online segmentation

Many variations on a simple segmentation paradigm have been used. Usually participants listen to a musical excerpt and are asked to indicate, by pressing a button or drawing a line on a musical score, whenever they hear a 'break' in the sequence, so that events that belong together go together. The sequences are constructed in such a way as to establish whether each type of segmentation is used, as well as to indicate the relative importance of each segmentation principle.

Arguments in favour of universal status

Comparisons across musical skill levels. Grouping appears unaffected by musical training, as similar segmentation principles are observed for adult musicians and nonmusicians, although musicians are more systematic in their responses.[6–8]

Infants. Grouping also appears to function from an early age. For instance, studies using a gap detection paradigm suggest that six- to eight-month-old infants segment in a similar fashion to adults, at least for timbre and pitch, although a much greater pitch change was necessary for infants compared with adults.[9,10]

Comparisons across ages. Findings are even less clear in children. Among the few previous studies on rhythmic development, we often find suggestions that this sort of grouping process is functioning in relatively young (five- to seven-year-old) children. However, these studies employ extremely indirect methodologies, and the conclusions are tentative.[10–15] With this criticism in mind, a major research project has been undertaken to examine the principles governing segmentation in 4- to 12-year-old musician and nonmusician children.[16] The children's task was to listen to short musical sequences composed of nine tones and to indicate, during a second listening, the point at which they would break the sequence into two (group boundary). Each sequence contained two changes in either pitch, intensity, tone duration, or pause duration. The question was whether or not their perceived boundaries were induced by the physical changes in the sequence, as observed previously in adults. The results provide a clear answer to this question: segmentations were well above chance level for all four segmentation principles, even for the youngest children (four years). On average, more than three-quarters of the segmentations corresponded to the physical change; this effect was equally strong for the four indices (pitch, intensity, tone duration, and pause duration). There was a slight improvement with age and musical experience, probably due to improved task-related skills.

Comparisons across cultures. The online segmentation paradigm can easily be adapted for intercultural research, as the stimuli are nonculture-specific, and the task does not require any specific learned skill. If these basic processes of segmentation and grouping are unaffected by experience with a particular type of sequence, then the same types of segmentation should be observed in all cultures.

Candidate 2: predisposition towards regularity

Processing is better for regular than irregular sequences. We tend to hear as regular sequences that are not really regular.

As mentioned above, rather than coding the precise duration of each interval, our perceptual system compares each newly arriving interval with preceding ones. If the new interval is similar in duration to preceding intervals (within an acceptable temporal window, the 'tolerance window'), it will be categorized as 'same'; if it is significantly longer or shorter than the preceding intervals (beyond the tolerance window), it will be categorized as 'different'. There may be an additional coding of 'longer' or 'shorter'. Thus, our system may code two or three categories of durations (same/different, or same/longer/shorter); but note that this is a relative, rather than absolute, coding system.

One consequence of this type of processing is that if a sequence is irregular (each interval has a different duration) but all the intervals remain within the tolerance window, then we will perceive this sequence as the succession of 'same' intervals and so perceive a regular sequence. Such a tolerance in our perceptual system is quite understandable when we examine the temporal microstructure of performed music: local lengthenings and shortenings of more than 10 per cent are quite common[17,18] and are not necessarily picked out by listeners as irregularities.[19]

Paradigm 2: tempo discrimination for regular and irregular sequences

This predisposition towards regularity has been investigated using a tempo discrimination paradigm. Listeners hear two sequences that differ slightly in tempo, and they must say which is the fastest. The degree of regularity of the sequences is varied from completely regular (isochronous) to extremely irregular (based on the standard deviation of the interval durations).[20] Results show that up to a certain degree of irregularity, irregular sequences are processed as well as the regular sequences: they are 'assimilated' towards regularity. However, above a certain degree of irregularity, discrimination performance drops considerably. This cut-off point corresponds to the tolerance window mentioned above.

Arguments in favour of universal status

Comparisons across musical skill levels. The tolerance window appears to function in a similar fashion for both musicians and nonmusicians, with slightly irregular sequences being assimilated to regular sequences, although temporal thresholds are lower in musicians than nonmusicians.[20]

Comparison across ages. To our knowledge, nothing is known about children's ability to process irregular sequences. We do know, however, that from the age of four years, children are able to detect a small change in tempo of an isochronous sequence.[21] Another way of demonstrating the importance of temporal regularity in processing sequences involves rhythm reproduction tasks. For instance, when five- and seven-year-old children reproduced both regular and irregular rhythms, performance was much better for the regular ones.[22]

Infants. We also know little about infants' ability to process irregular sequences. We do know, however, that the capacity to detect a small change in tempo of an isochronous sequence is already functional at two months in infants.[23] They are able to habituate to a particular tempo, and there is a reaction to novelty if the tempo changes.

Comparison across cultures. This tempo discrimination task for regular and irregular sequences is easily adaptable to people from other cultures. If this process is universal, we should observe the same low tempo discrimination thresholds for regular and slightly irregular sequences, with considerably higher thresholds for very irregular sequences.

Candidate 3: active search for regularity

We spontaneously search for temporal regularities and organize events around this perceived regularity.

Coding events in terms of temporal regularity is thus an economical processing principle, and it has implications. If an incoming sequence can be coded in such a fashion, the needed processing resources are reduced, thus making it easier to process such a sequence. Indeed, we can say that the perceptual system exploits this predisposition, by actively 'looking for' temporal regularities in all types of sequences. We therefore suggest that when listening to a piece of music, we are predisposed to finding a regular pulse, that which is emphasised by tapping our foot in time with the music (*tactus* in musical terms). Once this underlying pulse has been identified, it is used as an organizational framework around which other events are situated.

Paradigm 3: synchronization with musical sequences

A simple way of investigating this process is to ask people to listen to a musical sequence, and then to tap in time with the music in a regular fashion at the rate that they think 'goes best' with the music. Synchronization is considered to be accomplished if successive taps coincide with tones within the music (at a particular hierarchical level) within a 10 per cent window. This is quite a strict criteria when you take into consideration the considerable temporal variations observed in performed music. In order to accomplish this task, listeners must abstract an underlying regularity, even if the performance variations tend to mask 'pure' temporal regularity.

Arguments in favour of universal status

Comparison across musical skill levels. Synchronization success rates for both musicians and nonmusicians are very high (more than 90 per cent) when they are asked to tap in synchrony with music, even if the music contains many temporal and other performance microvariations.[24]

Comparison across ages. All 20 four-year-olds (as well as the older children aged 6–10 years) examined in our study were able to successfully synchronize with the beginning of Ravel's *Boléro*.[21]

Infants. Infants are able to adapt their spontaneous sucking rate to the rate of an auditory sequence,[25] at least under certain circumstances.

Comparison across cultures. In order to adapt this paradigm to intercultural research, musical excerpts must be selected to include both music that respects the temporal structure with which the participants are familiar (their own musical idiom) and music that does not.

Candidate 4: temporal zone of optimal processing

We process information best if it arrives at an intermediate rate.

A fourth processing principle concerns the rate of temporal sequences. People spontaneously 'listen for' important events occurring at equally spaced moments in time, and the rate at which they 'search for' important information is specific to each individual.[26,27] Thus, the search for temporal regularities described above occurs at a particular rate. A zone of optimal processing has been demonstrated with numerous paradigms and types of sequences. The results are concordant: sensitivity to change is highest if events occur about every 600 ms, with a range stretching between about 300 and 800 ms interonset interval (IOI).

Paradigm 4: irregularity detection in complex sequences

How can we demonstrate that people focus spontaneously on events occurring at intermediate rates? A first method is simply to compare tempo discrimination thresholds of different rates,[20] as mentioned above. However, a more ecologically valid paradigm is currently being developed that would be ideal for the present requirements. When participants listen to complex sequences composed of two cooccurring isochronous subsequences, they should focus on the subsequence closest in rate to the optimal processing zone (300–800 ms IOI). We therefore introduce a temporal irregularity into one of the subsequences, which listeners should be able to detect only if they are focusing on that particular subsequence. The overall rate of the complex sequence is varied from very fast to very slow. Our results indicate that, as expected, detection was better for the slowest subsequence when the complex sequence was fast, and better for the fastest subsequence when the complex sequence was slow.[28] This promising paradigm has been applied only to nonmusician adults.

Arguments in favour of universal status

Comparison across musical skill levels. Although musicians demonstrate a wider range of optimal tempi than nonmusicians, this optimal zone is still centred around the same value of 600 ms IOI.[20]

Comparison across ages. Children between the ages of 4 and 10 years also demonstrate the same zone of optimal tempi, although the range increases with age.[21]

Infants. Two-month-old infants demonstrate a reaction to novelty only for sequences at 600 ms IOI, demonstrating the same optimal zone from a very young age.[23]

Comparison across cultures. This paradigm can be easily adapted to people of other cultures.

Candidate 5: predisposition towards simple duration ratios

We tend to hear a time interval as twice as long or short as previous intervals.

A fifth principle concerns the perceptual status of the 'longer' and 'shorter' durations: longer time intervals tend to be perceived and produced twice as long as the 'same' intervals, and shorter intervals tend to be perceived and produced twice as short as the same intervals.[29–31] The implication is that a categorization process is involved here, with clear-cut passages from one category to another.[30,32] Such an organization principle results in the dominance of binary, rather than ternary or more complex ratios between the three categories of intervals.

Paradigm 5: rhythm reproduction

One consequence of this process is that people are better able to reproduce rhythms containing only 1:2 ratios than rhythms containing 1:3 ratios[33] or even more complicated ratios.[34] Also, when people reproduce complex musical rhythms, the duration of some intervals undergoes a distortion towards one of the categories—that is, the rhythm is simplified so that the produced intervals respect a 1:2 ratio.[29]

Arguments in favour of universal status

Comparison across musical skill levels. The same pattern of perceptual and motor distortions are observed in musicians and nonmusicians.[34]

Comparison across ages. From the age of 5 years, children are able to reproduce short rhythms based on binary (1:2), but not ternary (1:3) ratios.[33] When five- and seven-year-old children reproduce complex rhythms, their reproductions undergo simplification towards simple ratios.[22] Their incorrect reproductions contain only two durations, in a 2:1 ratio.[22]

Infants. To our knowledge, no data exists concerning the functioning of this duration categorization process in infants.

Comparison across cultures. A rhythm reproduction task can be adapted for intercultural research. Participants can be asked to reproduce rhythms varying in the number of different durations they contain. Reproductions should be best when they contain only two different durations in a ratio of 1:2. Ratios of 1:3 should be harder, and more complex ratios (which are perceived as irregular—see Candidate 2) even harder. The reproductions of complex rhythms should demonstrate simplification towards simple ratios.

Conclusion

We have thus proposed a series of five experimental paradigms, designed and tested to demonstrate the functioning of five temporal processes. If our hypotheses are correct concerning the universal nature of these processes, then whatever the culture or origin of the people being tested, we should observe the same results. This list of potential candidates for the status of temporal universals is probably far from complete, but it provides a starting point. Further suggestions are welcome.

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