Temporal expectations and their violations

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Chapter 4

Rhythmic complexity and metric salience

Ladinig, O. & Honing, H. (under revision). Complexity judgments as a measure of event salience in musical rhythms.[1]

Abstract

This study investigates potential differences between musicians and non-musicians in their perception of meter. Listeners with a variety of musical backgrounds were asked to judge the complexity of rhythms with 4/4 time signature in a Web-based perception experiment ($N = 101$). The complexity judgments were used to derive salience values for each metric position in the rhythms, for each listener group. The judgments of the two groups were quite similar regarding the influence of the levels of metrical (hierarchical) processing. Differences between the two groups were found regarding the additional influence of the absolute position of an event in a bar (serial position effect). Listeners in both groups perceived a rhythm as more complex when syncopation occurred on an early beat of a bar than when syncopation occurred on the last beat (primacy effect). For non-musicians only, this effect could be observed on the subbeat level as well, and furthermore, a rise in salience for events at the end of a bar was found (recency effect). We propose two variants of a model of syncopation perception, one for musicians and one for non-musicians.

[1]The experiment can be found at http://cf.hum.uva.nl/mmm/exp4/

4.1 Introduction

Listener's expectations influence their perception, and in the case of musical rhythm, expectations exist about *when* an event will occur. The expectations are not the same for every event, and some events will be more and others less expected. Some events are expected very strongly, and this expectation is seen as being the basis for *beat induction* - a process in which a regular isochronous pattern (the beat) is activated internally while listening to music (for a recent overview see Patel, 2008). The *beat* (also termed *pulse* or *tactus*) is essential for time-keeping in music performance and affects the processing, coding, and appreciation of temporal patterns. Beats are positions in a rhythm that often coincide with spontaneous rhythmic behavior, like clapping hands or stomping while dancing (London, 2004; Parncutt, 1994), and there is a preference for beats to occur at intervals of about 600 msec. The induced beat underlies the perception of tempo and is the basis of temporal coding in music. Furthermore, it determines the relative importance of notes in the melodic and harmonic structure of music (Desain & Honing, 1999). Events between beats are subordinate to them, and are perceived as the weak events of a rhythm, in this paper referred to as *subbeats*. In most common Western rhythms, subbeats divide inter-beat intervals into parts whose durations form simple ratios such as 1:1, 2:1, or 3:1.

When at least two levels of metric structure are active during perception one speaks of *metric processing* (London, 2004; Yeston, 1976). The *event salience*, or sometimes termed metric salience, of a position within a pattern refers to the structural level the position is assigned to, which is an indicator of its importance relative to other positions within a certain metrical unit (e.g., bar). In general, events in positions that are perceived as salient are memorized and recalled easier, attract primary attention, are more expected to occur, and, when they are absent, lead to the impression of rhythmic complexity (Fitch & Rosenfeld, 2007; Pressing, 2002). Different theoretical models of meter perception make alternative predictions about the structure and the depth of the metric hierarchy of a rhythmic pattern.

4.1.1 Musicians vs non-musicians

There exist several conflicting theories about the influence of formal musical training on the perception of metric structure. Palmer and Krumhansl (1990) and Jongsma et al. (2004) reported differences between musicians and non-musicians. Palmer and Krumhansl analyzed goodness-of-fit judgments for single events presented in 16 positions within a 4/4 metric context; Jongsma et al. collected ERP as well as goodness-of-fit data for single events presented in seven positions within a duple and a triple metrical context. Musical training seemed to enhance depth of processing, allowing for the perception of more than two metrical levels at the same time. Palmer and Krumhansl found periodicities in the responses of non-musicians only for those positions that constitute the beat level, whereas musicians showed periodicities in their responses on lower metrical levels as well, displayed in a hierarchical structure of the positions between two beats. Results of Jongsma and colleagues are in line with those findings, but further suggest that non-musicians process temporal patterns in a more serial (as opposed to hierarchical) fashion, with a higher expectation for events to occur at the beginning of a bar.

Recently, several studies have indicated that non-musicians are more musically competent than previously thought. For example, Bigand and Poulin-Charronnat (2006), and Honing and Ladinig (2009) found evidence that if tasks and modes of responding do not require specialized training, differences between musicians and non-musicians tend to disappear.

4.1.2 Rhythmic complexity and syncopation

Several researchers have attempted to define and formalize rhythmic complexity (Essens, 1995; Pressing, 2002; Shmulevich & Povel, 2000; for an overview see Streich, 2007), but there has been little empirical validation of their models and little agreement regarding definitions of crucial concepts. In this study, perceived rhythmic complexity is thought of as being approximated by the concept of *syncopation*. Syncopation is the music-theoretical term for a moment in the music where there is a strong metric expectation that is not confirmed with a note onset. Some authors refer to this as a *loud rest* (London, 1993). A formalization of syncopation was proposed by Longuet-Higgins and Lee (1984), and is referred to as the *L-model* here. It recursively breaks down a rhythmic pattern of specific length into equal subparts, and assigns to every event a weight relating to its metrical level, assuming a metric hierarchy of maximal depth (see description of model A in the following section). For example, for a typical bar in Western music, with a 4/4 time signature and the smallest note being a 16th note, this would imply five distinct levels of event salience (e.g., Lerdahl & Jackendoff, 1983; Longuet-Higgins & Lee, 1984). The L-model assumes that syncopation occurs if a rest or a tied note is at a higher metrical level than the immediately preceding sounding note, with the strength of the syncopation being the difference between the metrical levels of the note and the rest.

There exist two data-sets of complexity judgments in the literature. Shmulevich and Povel (2000) collected judgments of musicians, whereas Essens (1995) collected judgments of both musicians and non-musicians. The L-model accounted fairly well for the Shmulevich and Povel data, as shown by Smith and Honing (2006). For the data collected by Essens, such correlations with model predictions have not yet been reported.

The current paper first describes testable hypotheses derived from four models that differ in their assumptions regarding the salience values they assign to each metric position of a bar. Subsequently we describe test results that enabled us to derive empirically based event salience values for the average listener as well as for musicians and non-musicians separately, consisting of a metrical component and of a new component reflecting the serial position of events. We obtained these data by collecting complexity judgments about regular and syncopated rhythms.

By substituting our empirically derived salience values for the salience values assigned by the standard L-model, we generated two variants of the L-model, one for musicians and one for non-musicians. Since the new salience values are based on judgments of complexity rather than of syncopation (unlike the L-model), the resulting model variants may be suitable for specifying the complexity of a rhythm, which is here seen as superordinate to the syncopatedness of a rhythm.

4.2 Theoretical models

In this section we present four theoretical models that will enable us to construct hypotheses. The models, some of which are derived from the literature, vary in their degree of explicitness regarding the level of formalization. We also describe an empirical method for testing the relevant hypotheses. A visual representation of the four models can be found in Figure 4.1. The dotted lines represent the specified metrical levels; the dashed line indicates which events lie above or below the tactus level.

4.2.1 Model A

Model A is the L-Model, explained in the previous section. This model assumes that listeners impose as many metrical levels as possible on a rhythm. Empirical evidence for this model as representing the event salience values perceived by musicians comes from Palmer and Krumhansl (1990) and Jongsma et al. (2004). Additionally, Palmer and Krumhansl calculated frequency distributions of event onsets from a corpus of notated Western classical music, and the high correlation of those values with the event salience values perceived by musicians supports the model.

4.2.2 Model B

The same two studies (Jongsma et al., 2004; Palmer & Krumhansl, 1990), which support model A with data gathered from musicians, suggest a limited model of metric structure and event salience for non-musicians, which we call model B. As in model A, the values of event salience differ between the beat and the subbeat level, and also above the beat level (i.e., it assumes perception of a most important beat, the downbeat), but all events below the tactus belong to the same metric level and consequently have the same event salience.

4.2.3 Model C

Another model suggesting limited perception of metrical levels compared to model A is model C. This model again reflects the differentiation between beats and subbeats, but neglects the hierarchical structure of beats (no most salient beat, i.e., downbeat). Events below the beat level, however, are structured hierarchically and derived by recursive subdivision as in model A. A related formalization has recently been suggested by Gomez, Melvin, Rapaport, and Toussaint (2005), but so far has not been empirically validated.

4.2.4 Model D

A fourth model is introduced for the sake of completeness. It depicts a possible representation of the most basic metrical structure (Yeston, 1976), which contains only two different metric levels to which events are assigned: the beat and the subbeat level.

4.3 Hypotheses

We restricted this study to duple meter and a constant tempo (600 ms inter-beat interval), and kept the number of notes constant. We used rhythms commonly expressed in a 4/4 time signature, with 16 equally spaced positions of possible event onsets. We will refer to positions 1, 5, 9, and 13 as *beats*, and to all remaining positions as *subbeats*. All subbeats between two beats are considered as belonging to the same *subbeat cluster*.

To evaluate the four models of event salience, we tested the following hypotheses regarding perceived event salience:

Beat differentiation hypothesis: This hypothesis (models A and B) predicts differences in perceived event salience among the events that constitute the beat, showing a weak-strong-weak pattern following an initial downbeat. The corresponding null hypothesis (models C and D) predicts no differences in salience judgments given to beat events.

Subbeat differentiation hypothesis: This hypothesis (models A and C) predicts differences in perceived event salience among the events in each subbeat cluster, showing a weak-strong-weak pattern. The corresponding null hypothesis (models B and D) predicts no differences in the salience judgments for subbeats within a cluster.

Subbeat cluster differentiation hypothesis: This hypothesis is not based on any of the introduced models, but derives from an empirical finding by Jongsma et al. (2004), which predicts differences in salience judgments due to the position of the subbeat cluster within the bar (serial position effect). Events at the beginning of a bar may be perceived as more salient than events in the remainder of a bar. The corresponding null hypothesis (models A to D) predicts no such differences.

Beat/Subbeat relation hypothesis: This hypothesis (all models) predicts differences in perceived event salience between the beat and the subbeat level, with the beat positions receiving higher salience than the subbeat positions. The corresponding null hypothesis (not expressed in any of the introduced models) predicts no differences, and respective results would not only converse models of meter induction, but also models of beat induction.

Expertise hypothesis: Musicians are predicted to have an elaborate metrical hierarchy (model A), leading to differentiation of beats as well as subbeats. Non-musicians are predicted to show a less developed metrical structure in their salience judgments (models B, C, or D).

4.4 Methods

The purpose of the experiment was to collect relative complexity judgments about regular and syncopated rhythms. We used an online Web-based setup (see Honing & Ladinig, 2008, for a discussion of the pros and cons of this relatively novel method).

4.4.1 Participants

Invitations were sent to various mailing lists, online forums, and universities, to reach a wide variety of respondents. From the 200 initial respondents, we excluded 29% because they did not finish the experiment or did it too quickly. The remaining participants (N = 142) were between 17 and 63 years old (*Mode* = 20, M = 32.7, *SD* = 11.73) and had various musical backgrounds, ranging from no musical training up to 30 years of training. After excluding participants who could not clearly be classified as either being a musician or a non-musician (see below for the criteria), 101 participants remained in the sample, which were between 17 and 63 years old (*Modes* = 20 and 30, M = 34.2, *SD* = 12.25) and had a range of years of musical training from zero up to 30 years.

4.4.2 Equipment

Rhythmic stimuli were constructed using custom software and converted to MPEG-4 file format to guarantee consistent sound quality on different computer platforms and to minimize download time. The sounds were drum samples ("bongos") taken from the EZdrummer EZX Latin Percussion sample set ("Toontrack").

4.4.3 Stimuli

Sixteen rhythms, either syncopated or regular according to the definition by Longuet-Higgins and Lee (1984), were constructed (S01 - S16) and combined into seven stimulus sets, each consisting of two to four stimuli (see Figure 4.2). Small sets of stimuli were used for two reasons: First, to get clear indications of the differences in perceived complexity for a stimulus relative to certain other stimuli, as opposed to using judgments relative to the whole range of rhythms tested. And second, to employ ranking scales, as opposed to rating scales, with the former being less prone to ceiling or floor effects. The inter-onset interval (IOI) of consecutive 16th notes was 125 ms. The first position in each rhythm was marked with a louder sound to prevent listeners from perceiving it as an upbeat. Each rhythm was repeated four times without a break. Two different drum sounds (high and low congas) were used in alternation for the repetitions.

Stimulus sets 1-4 tested the structure of event salience on the subbeat level, according to the subbeat differentiation hypothesis, for subbeat clusters 1, 2, 3, and 4, respectively. Each set contained three rhythms. They had events on every beat and on two of the three subbeats within one inter-beat interval. Listeners had to compare the three stimuli within each set with regard to their perceived complexity.

Stimulus set 5 tested whether or not there are differences in event salience on the beat level, according to the beat differentiation hypothesis. Three stimuli were constructed that had events in only every other metrical position (i.e., a beat with simple subdivisions). One of the three beat events following the initial downbeat was omitted. Listeners were asked to compare the rhythms according to their perceived complexity. Stimulus set 6 was intended to shed light on whether the serial position of an invariant subbeat cluster within the rhythm affected perceived complexity, according to the subbeat cluster differentiation hypothesis. Listeners compared four stimuli, in which the same rhythmic pattern constructed of subbeats within one cluster (second and third subbeats only) occurred after beat 1, 2, 3, and 4, respectively.

Finally, stimulus set 7 provided a direct comparison of syncopation at the beat and subbeat levels. Both patterns in this set had events in the 1st, 2nd and 4th beat positions, and in the second and third subbeat position of subbeat cluster 3. The difference was that one pattern had an event on the third beat, and none on the first position of subbeat cluster 3 (subbeat syncopation), and the other pattern had no event on the third beat, but one on the first position of subbeat cluster 3 (beat syncopation).

4.4.4 Procedure

Participants were invited to visit a Web page of the experiment. They were instructed by a short screen-cast, showing examples of the experiment while the instructions were narrated, with an option to access written instructions as well. The instructions were as follows:

> In this experiment we are interested in your judgments on rhythmic complexity. We will present you seven boxes containing 2 to 4 rhythms each, and we ask you to make a judgment on the complexity of the rhythms in relation to the other rhythms within the same box (referred to as 'comparisons').
> Rhythmic complexity can be understood as a feeling of rhythmical tension, the violation of your expectation, a deviation of a regular rhythmic pattern, or non-predictability of events.
> For each of the seven sets of comparisons we ask you to listen through the whole sound samples, and, according to your perception, either 1) mark all rhythms in a box to be of equal complexity, or 2) rate their complexity on a 2 to 4 point scale (depending on the number of rhythms) where a low number indicates low complexity and a high number high complexity.
> Every rhythm is repeated four times with the percussion sounds varying for every repetition. All rhythms are played in the same tempo. You can listen to the rhythms as often as you like before making the judgment.
> N.B. There is no right or wrong answer; we are simply interested in your subjective, personal judgments.

The participants made their complexity judgments on a ranking scale that had as many increments as there where rhythms to compare in a set. The sets as well as the rhythms within each set were shown on the screen in random order. At the end of the test we asked for information about musical experience and age. We left some space for comments and feedback. The whole task typically took about 15 minutes to complete. We recorded the total time from the moment the subject started the experiment until the response form was sent, to ensure that the subject listened to all stimuli.

4.5 Data analysis

The responses were tabulated for further analysis with POCO (Honing, 1990), music software for symbolic and numerical analyses, and SPSS (Version 11) for statistical analyses.

4.5.1 Grouping by musical experience

We constructed two categories, musicians and non-musicians, and assigned participants to either of those groups. The category of musicians ($N = 57$) consisted of subjects that had between eight and 30 years of musical training (M = 15.9 years) that had started when they were between three and eight years old (M = 6.5 years). The non-musicians (N = 44) had either no formal musical training at all or had started after the age of eight (M = 17.2 years) and received training for a maximum of four years (M = 2.6). The remaining participants were excluded from the analyses.

4.6 Results

Statistical results regarding the difference between musicians and non-musicians are tested with the Wilcoxon Mann-Whitney test. Statistical results regarding the beat differentiation hypothesis, the four subbeat differentiation hypotheses, the subbeat cluster differentiation hypothesis, and the beat/subbeat relation hypothesis were tested with Friedman ANOVAs. Significant results were further analysed by obtaining pairwise comparisons using Wilcoxon tests for signed ranks with Bonferroni corrections. Mean values for all stimuli are reported in Table 4.1.

4.6.1 Differences according to musical expertise

For each stimulus, differences in responses between musicians and non-musicians were tested. Each reported Mann-Whitney U-value is based on $N = 57$ for musicians and $N = 44$ for non-musicians. Judgments differed significantly for S04 in stimulus set 2 ($U = 1012.5$, $p < .05$) and S10 in stimulus set 4 ($U = 919$, $p < .01$), and for S01 ($U = 986$, $p < .05$), S04 ($U = 861.5$, $p < .01$), and S10 ($U = 854.5$, $p < .001$), when presented in stimulus set 6.

4.6.2 Beat differentiation hypothesis

To test the beat differentiation hypothesis, judgments given to the stimuli of set 5 were compared. The hypothesis predicts a weak-strong-weak pattern of the three beats, with differences between the second and the third and the third and the fourth beat, but no differences between the second and the fourth beat. In other words, S14 was predicted to be judged as more complex than S13 and S15. The null hypothesis predicts no differences in judgments regarding the three stimuli. For both musicians and non-musicians, significant differences were found between the second and fourth beat, and the third and the fourth beat, but not between the second and the third beat of a bar, indicating a strong-strong-weak pattern. Thus the beat discrimination hypothesis was not confirmed, but the judgments also were not equal.

4.6.3 Subbeat differentiation hypothesis

The subbeat differentiation hypothesis suggests a weak-strong-weak pattern for each subbeat cluster individually. That is, in stimulus sets 1-4, each central stimulus was expected to be judged as more complex than the two corresponding outer stimuli. For musicians, this pattern was confirmed for all subbeat clusters. For non-musicians, this pattern was only shown for subbeat clusters one, three, and four. For subbeat cluster two, a strong-weak-weak pattern was found.

4.6.4 Subbeat cluster differentiation hypothesis

The subbeat cluster differentiation hypothesis makes predictions about a serial position effect among the subbeat clusters, with stimuli having omissions at the beginning of a bar (S01 in the context of set 6) receiving higher complexity judgments than stimuli with omissions later in the bar (S04, S07, S10 in the context of set 6). For musicians, the responses did not show any serial position effect. Complexity judgments were equally high for each subbeat cluster. For non-musicians, the responses among the subbeat clusters displayed significantly lower judgments to subbeat cluster three when compared to judgments to subbeat clusters two and four. No differences were found between subbeat cluster one and any other subbeat cluster.

4.6.5 Beat/Subbeat relation hypothesis

The beat/subbeat relation hypothesis suggests that an omission in a beat position would lead to higher complexity judgments than an omission in a subbeat position. in stimulus set 7, S16 was predicted to be judged as more complex than S07. For both musicians and non-musicians, this hypothesis was confirmed.

4.6.6 Conversion of complexity judgments into values of event salience

Participants had judged perceived complexity of rhythmic stimuli relative to one, two, or three other stimuli within the same stimulus set (see Figure 4.2). Those rankings were used for the statistical hypothesis testing reported above. To use the data as event salience values for each position in a rhythm (i.e., as values for variants of the L-model), conversions are necessary, which we will illustrate here with the non-musicians' data. The rhythms in each set can be regarded as differing in the position in which an event is omitted. Consequently, complexity judgments about a rhythmic stimulus are seen here as related to the event salience of the position of the omission. The average judgments of complexity for stimuli 01-12 in the context of stimulus sets 1-4 were taken directly as salience values for each subbeat position in a bar (see Figure 4.3, Step 1). The judgments given to stimuli in set 6 (where the same subbeat pattern occurred in different positions between beats) were added to each subbeat of the subbeat cluster represented in the stimulus (see Figure 4.3, Steps 2 and 3). They were treated as weights of each subbeat cluster within the whole measure, but leave the internal structure of each subbeat cluster intact. The resulting values were rescaled to values between 0 and 1. This was done because the judgments of stimulus set 7 indicated that participants perceived a violation of regularity on the beat level as more complex than a violation on the subbeat level. To account for this, the lowest beat position values had to be made higher than the highest subbeat position value (see Figure 4.3, Step 3). The average judgments to stimuli 13-15 were taken directly as salience values for each beat position (see Figure 4.3, Step 4). In a last step, subbeats and beats were combined (see Figure 4.3, Step 5).

4.6.7 Schematization of event salience

The derived salience values were expressed schematically as hierarchical structures, like the models shown in Figure 4.1, with each visible difference representing a significant difference in the data. None of the four proposed theoretical models of event salience could be fully validated, especially since a serial position effect occurred. Therefore we constructed two new models, one for musicians, and one for non-musicians. Figure 4.4 represents the metric processing of the different listener types, and so only the values from the judgments of stimulus sets 1-5 are considered. If significant differences exist, these are represented as differences in length of vertical lines among the subbeats belonging to one subbeat cluster, and among the beat positions. In Figure 4.5, judgments of stimulus set 6 are plotted, which represent serial processing. Figure 4.6, finally, is a combination of Figures 4.4 and 4.5. All subbeats from the subbeat-cluster that received a higher rating will be higher in salience than any subbeat from the subbeat-cluster that received a lower rating. Subbeat-cluster values that are not significantly different from either of the enclosing subbeat clusters are assigned values that overlap with the values of both enclosing subbeat clusters. In other words, if the lines of two subbeat clusters have any overlapping values, no significant difference was found between those two subbeat clusters.

4.7 Discussion and Conclusion

Contrary to what has been found in some previous studies (Jongsma et al., 2004; Palmer & Krumhansl, 1990), we found musicians and non-musicians to behave similarly in terms of hierarchical processing (see section 'Metric processing' below), but substantially different regarding the serial position of events (see section 'Serial processing' below), as assessed in terms of event salience estimates derived from complexity judgments. By using musically plausible stimulus patterns rather than probe-tones, and small sets of rhythms to compare, we gave non-musicians a chance to respond in a more natural setting. Skills that are typically very developed in musicians, like the precise subdivision of silent intervals, that can lead to good performance in temporal probe-tone tasks, were not required or in any way helpful in the current experiment.

4.7.1 Metric processing

With the exception of the second subbeat cluster in non-musicians, both musicians and non-musicians discriminated between subbeats in a hierarchical weak - strong - weak fashion. Why non-musicians differ from musicians (as well as from their own responses to the other subbeat clusters) in subbeat cluster 2 is not clear. Both listener groups showed some metric structuring on the beat level, although not in line with the predictions of any of the models we considered. While the two last beats, positions nine and thirteen, showed the expected strong-weak pattern, the second beat, position five, had a higher salience than expected, and thus has to be considered as a strong beat as well. Regardless of the differences from the proposed models, both musicians and non-musicians showed the same strong - strong - weak pattern on the beat level. We assume that a primacy effect comes into play here, which makes it more important for a rhythmic pattern to have events on earlier beats of a bar than on later beats, in order to establish a framework for meter. We consider the results for the beat level as consistent with hierarchical processing of the beat level, since the distribution shows significant differences regarding beat position four, and thus the distribution of beat saliencies is clearly not flat (excluding the first beat, which was strongest by definition).

4.7.2 Serial processing

Concerning the variation between subbeat clusters, we found effects for non-musicians, suggesting declining salience later in the bar compared to the beginning of the bar (*primacy effect*), and again a strong rise in salience at the end of the bar for non-musicians only (*recency effect*). Thus events at the beginning and the end of a pattern seemed more important than events in the middle. No serial position effect was found for musicians on the subbeat level; however, the fact that on the beat level they showed a deviation from a pure hierarchical structure at the beginning of a bar suggests a primacy effect for that listener group as well. It would be interesting to explore whether there are differences in the kinds of music musicians and non-musicians are typically exposed to. Some kinds of music, for example pop and rock, show a high tendency for upbeats, which could be a possible explanation for the high salience that the last subbeat cluster receives for non-musicians.

4.7.3 Analytic vs. heuristic listening

In order to construct a model of metrical perception that is valid for listeners from various musical backgrounds it seems to be appropriate to keep a fully metrical model for all listeners and add a serial component, which we found to be more important in listeners with less formal musical training. According to our data, the serial position effect that all listeners show is a primacy effect on the beat level. However, non-musicians in addition showed primacy and recency effects on the subbeat level as well. These results tempt us to speculate about the nature of processing of temporal information in general. Since we used rhythms that were arguably familiar to our participants, in 4/4 time-signature at a moderate tempo, probably not much cognitive effort had to be expended to relate the stimuli to known musical materials. Thereby, simple heuristic mechanisms could have come into play. Serial processing of temporal information can be seen as a quick way of grasping the structure of a rhythm, without detailed analytical, hierarchical processing. This interpretation is supported by our finding that it is non-musicians who show a stronger serial position effect than musicians.

4.8 Acknowledgments

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4.9 Figures and tables

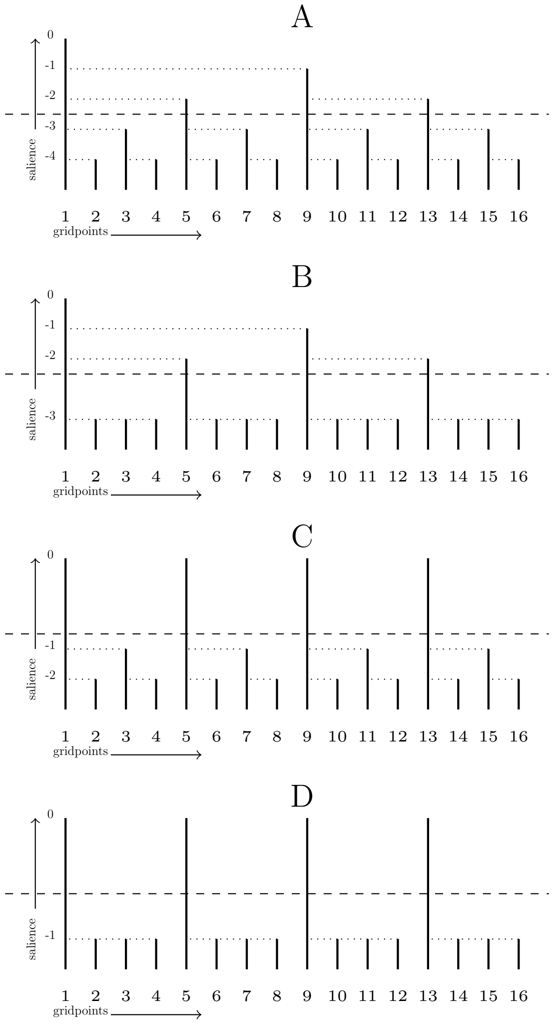

Figure 4.1: Four models of metrical structure. Predicted significant differences in event salience between grid-points within the duration of one bar (x-axis) are expressed using an ordinal scale (y-axis). The dashed lines indicate which events lie above or below the tactus

Pair	Musicians	Non-musicians
S01/S02 (SBC1)	1.28/2.12*	1.43/2.07*
S02/S03 (SBC1)	2.12/1.46*	2.07/1.68*
S01/S03 (SBC1)	1.28/1.46	1.43/1.68
S04/S05 (SBC2)	1.26/2.07*	1.52/1.84*
S05/S06 (SBC2)	2.07/1.44*	1.84/1.55
S04/S06 (SBC2)	1.26/1.44	1.52/1.55
S07/S08 (SBC3)	1.23/1.95*	1.43/1.91*
S08/S09 (SBC3)	1.95/1.39*	1.91/1.43*
S07/S09 (SBC3)	1.23/1.39	1.43/1.43
S10/S11 (SBC4)	1.30/2.26*	1.66/2.34*
S11/S12 (SBC4)	2.26/1.49*	2.34/1.43*
S10/S12 (SBC4)	1.30/1.49	1.66/1.43
S13/S14 (B)	1.72/1.65	2.05/1.75
S14/S15 (B)	1.65/1.28*	1.75/1.39*
S13/S15 (B)	1.72/1.28*	2.05/1.39*
S01/S04 (BSBC)	1.61/1.51	2.02/2.02
S01/S07 (BSBC)	1.61/1.33	2.02/1.55
S01/S10 (BSBC)	1.61/1.46	2.02/2.07
S04/S07 (BSBC)	1.51/1.33	2.02/1.55*
S04/S10 (BSBC)	1.51/1.46	2.02/1.55
S07/S10 (BSBC)	1.33/1.46	1.55/2.07*
S16/S07 (BSBR)	1.88/1.00*	1.95/1.00*

Table 4.1: Mean values for the judgments to each stimulus are given for musicians and non-musicians. Asteriks mark significant differences according to the Wilcoxon statistics, testing beat discrimination, subbeat discrimination, and subbeat cluster discrimination hypotheses. Abbreviations used for stimuli are taken from Figure 4.2.

Stimulus set 1

Subbeat cluster 1 (SBC1)

S01 | . | | | . . . | . . . | . . .

S02 | | . | | . . . | . . . | . . .

S03 | | | . | . . . | . . . | . . .

Stimulus set 2

Subbeat cluster 2 (SBC2)

S04 | . . . | . | | | . . . | . . .

S05 | . . . | | . | | . . . | . . .

S06 | . . . | | | . | . . . | . . .

Stimulus set 3

Subbeat cluster 3 (SBC3)

S07 | . . . | . . . | . | | | . . .

S08 | . . . | . . . | | . | | . . .

S09 | . . . | . . . | | | . | . . .

Stimulus set 4

Subbeat cluster 4 (SBC4)

S10 | . . . | . . . | . . . | . | |

S11 | . . . | . . . | . . . | | . |

S12 | . . . | . . . | . . . | | | .

Stimulus set 5

Beat (B)

S13 | . | . . . | . | . | . | . | .

S14 | . | . | . | . . . | . | . | .

S15 | . | . | . | . | . | . . . | .

Stimulus set 6

Between subbeat clusters (BSBC)

S01 | . | | | . . . | . . . | . . .

S04 | . . . | . | | | . . . | . . .

S07 | . . . | . . . | . | | | . . .

S10 | . . . | . . . | . . . | . | |

Stimulus set 7

Beat/Subbeat relation (BSBR)

S16 | . . . | . . . . | | | | . . .

S07 | . . . | . . . | . | | | . . .

Figure 4.2: Stimuli. The x-axis indicates the grid position, '—' marks a note/sound, '.' marks a rest/silence

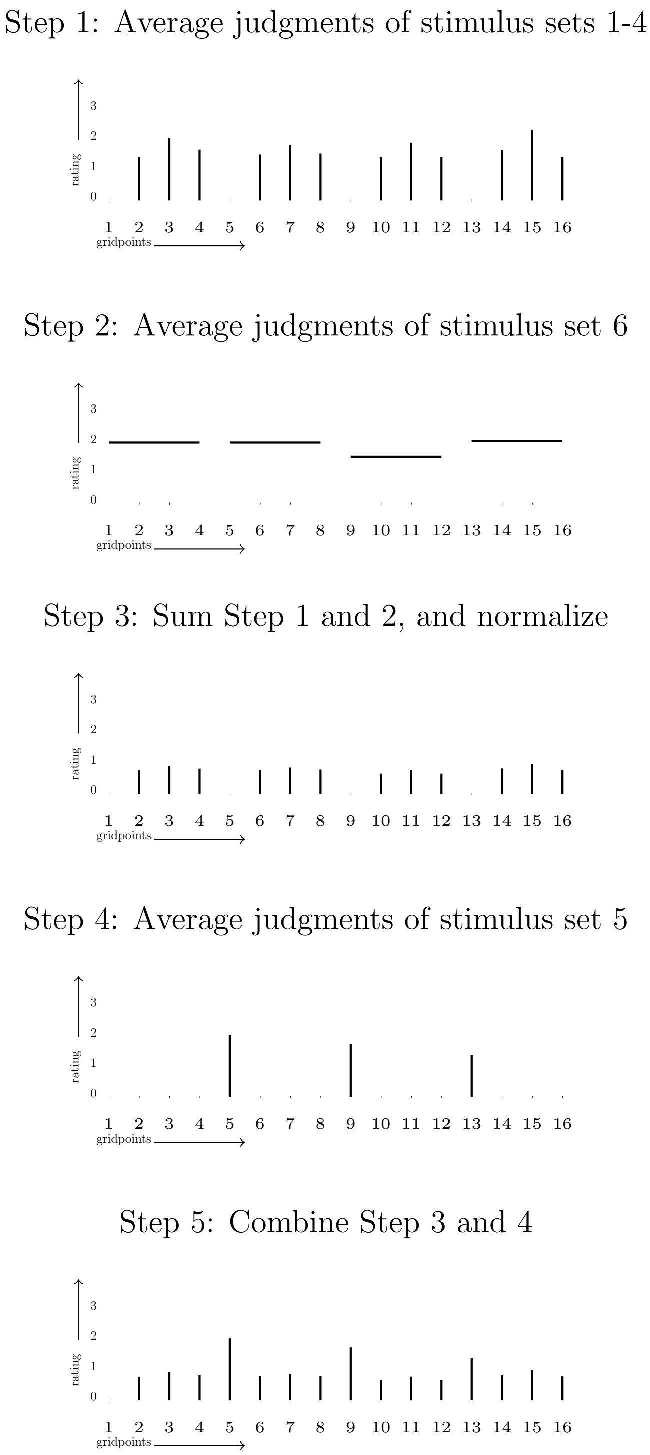

Figure 4.3: Example of conversion of complexity judgments to event salience values, using data of non-musicians

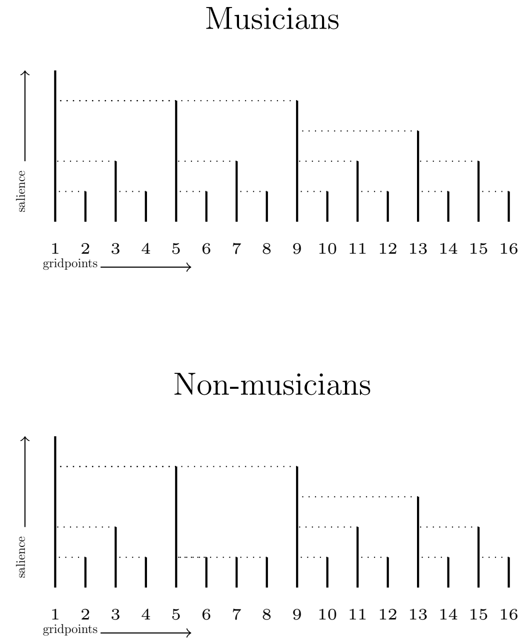

Figure 4.4: Results for beat and subbeat discrimination hypotheses for musicians and non-musicians. Significant differences in event salience between gridpoints within the duration of one bar (x-axis) are expressed using an ordinal scale (y-axis)

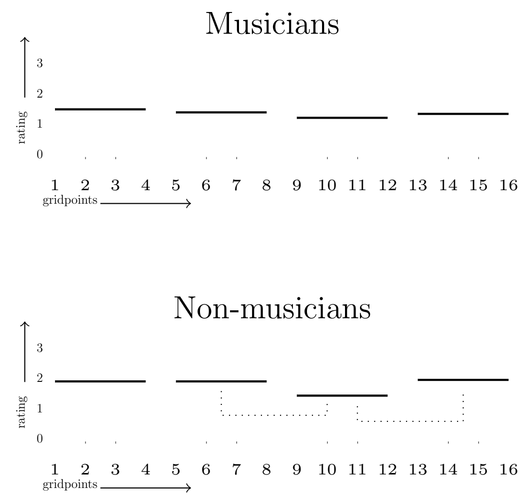

Figure 4.5: Results for serial position effect hypothesis among subbeat clusters for musicians and non-musicians. The x-axis represents gridpoints, the y-axis represents average ratings for the four subbeat-clusters (see stimulus set 6). Significant differences are indicated by dotted lines

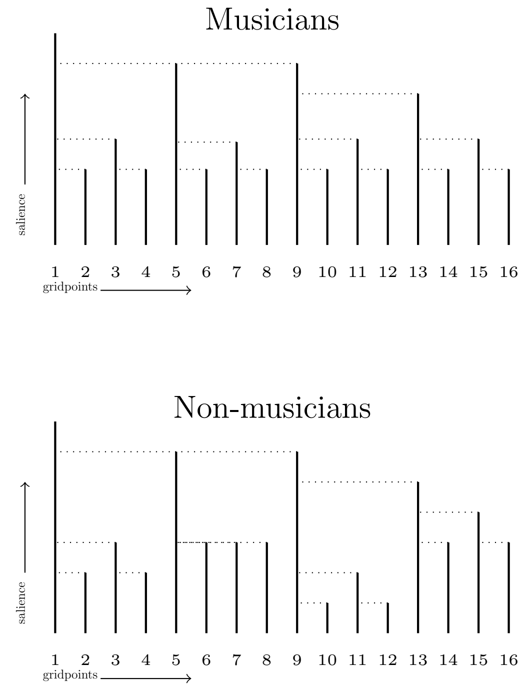

Figure 4.6: Final event salience profiles for musicians and non-musicians. The x-axis represents gridpoints, the y-axis represents event salience