MUSICAL STRUCTURE, LISTENER ORIENTATION, AND TIME PERCEPTION

Annekatrin Kessler
Richard Parncutt
Department of Musicology, University of Graz, Austria

ABSTRACT

Jones and Boltz (1989, 1993) proposed that a clear musical structure helps listeners predict future musical events and hence accurately perceive musical time. According to Fraisse (1963) and Ornstein (1969), poorly structured stimuli contain more perceptual elements and therefore seem to last longer.

Jones' and Boltz's experiments focussed on synthesized melodic fragments. We investigated whether their finding generalises to real music (excerpts from commercially available CDs) and musically typical durations (longer than a few seconds).

In Expt. 1, 15 listeners of mixed musical background heard 20 musical excerpts and rated their predictability, variability, closure, tempo, pleasantness and familiarity, as well as their own musical experience and their arousal and attention during the experiment. They also estimated the duration of each excerpt in seconds. Stimuli included examples of minimalism, classicism, atonality, jazz and non-western music. Each listener heard the excerpts in a different random order. Expt. 2 was identical except that the musical excerpts lasted for 3 minutes, and a new group of listeners participated. In neither experiment did any listener guess that all excerpts had the same duration.

Our clearest finding was an unexpectedly large effect of physical duration on estimated duration. In Expt. 1, the mean estimated duration was not significantly different from 30 sec., but in Expt. 2 it was 65% longer than 3 min.

Jones and Boltz predict that duration estimates are most accurate for highly predictable excerpts; Fraisse and Ornstein predict overestimation of duration for unpredictable excerpts. We did not find clear support for either of these theories.

Based on Berlyne's complexity theory and the theory of cognitive orientation by Kreitler and Kreitler, we expected the most accurate duration estimates for musical excerpts judged to have medium variability and predictability. In Expt. 1 (30 s), the most accurate duration estimates corresponded to medium variability and high predictability; in Expt. 2 (3 min), the most accurate duration estimates corresponded to low variability and medium predictability.

1. THEORETICAL BACKGROUND

Our approach to time perception is based on an ecological theory of perception (Gibson 1979) and the theory of cognitive orientation (Kreitler & Kreitler 1980). The human organism is understood to perceive and learns to understand its environment by the principle of *homeostasis*, or maintenance of equilibrium by dynamic interactive self-regulation. We choose situations that are neither too complex (making orientation difficult) nor too simple, preferring instead a medium amount of information. We try to avoid situations in which inner and outer information disagree (Rauterberg 1996). We also seek variability: when a situation becomes familiar, the degree of complexity decreases. As the drive to orient oneself is satisfied, the drive to explore takes over.

The perception of an unfamiliar, new event or situation is associated with physiological arousal. According to Berlyne (1972), a medium degree of arousal – and consequently of information – is aesthetically preferred. So the experience of the structure of a piece of music can be explained by the principles of everyday experience, which include tension and release, or expectation and confirmation/frustration (Wundt 1974).

Orientation involves expectancies based on past and present events. To be able to orient oneself in a certain situation or piece of music is to be able to anticipate future events. But according to Kreitler and Kreitler, a situation that is absolutely familiar does not satisfy our drive to explore, so expectancies will not be generated. That is why cognitive orientation corresponds to a medium degree of predictability.

Recent models of duration estimation (Jones & Boltz) predict high accuracy for highly coherent events, i.e. for events which enable the perceiver to anticipate the future course.

They argue that time can only be perceived by change and motion and by interacting with the inner temporal structure of an event, corresponding to temporal predictability. Combining this with the above arguments, we predict most accurate estimation for the greatest degree of orientation, i.e. medium predictability.

2. MODELS OF TIME ESTIMATION

Different models of duration estimation focus on different factors that influence time perception. The divergent and conflicting empirical results can be accounted for by divergent definitions of complexity and kinds of stimuli.

2.1. Memory-Storage Model

Ornstein's storage-size theory (1969) defines the complexity of a stimulus in terms of the amount of memory needed to store it. According to Ornstein, the experience of duration is a cognitive construct - an abstraction from its storage size. So as storage size increases, duration experience lengthens. This model predicts overestimation for more complex stimuli and has found empirical support for non-musical stimuli (Mulligan & Shiffman 1979, Shiffman & Bobko 1974).

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2.2. Cognitive Change Model

Fraisse (1963) argued that duration estimation depends on the number of perceptible changes within a time-span. The greater the number of discrete stimuli in the interval, the longer its experienced duration. Block and Reed (1978) extended Fraisse's concept of psychological change to include background stimuli, interceptive stimuli and psychological context (e.g. thoughts, associations). Block and Reed also predicted that the duration of new situations are overestimated because more changes are perceived.

2.3. Expectancy/Contrast Model

According to Jones and Boltz (1989) and Boltz (1992), it is not the amount of information within a time-span that determines its perceived duration but the way in which the event is structured. Coherent, i.e. hierarchical structured events enable the perceiver to predict their future course including when they will end. This *future-oriented* or *dynamic* attending mode leads to relatively precise duration estimates. Incoherent, non-hierarchical structured events force the perceiver to concentrate on local or adjacent events (*analytic attending*) which makes duration estimation more difficult. They also predict underestimation for coherent events that seem to end too early (*negative contrast*) and overestimation for coherent events that seem to end too late (*positive contrast*).

3. EXPERIMENTS

Our experiments differ from recent investigations in three main aspects:

1. We compared estimations of two different durations: 30 seconds and 3 minutes. Most empirical studies concerning duration estimation of musical events have used excerpts of about 10 to 50 seconds.

2. Instead of simple synthesised melodies we used real music (from conventional CDs) with a very wide range of styles.

3. We did not define complexity or musical structure objectively, but compared the *subjective* degree of cognitive orientation with estimated duration.

Based on the above-mentioned models and on our theoretical background we advanced the following hypotheses:

1. According to the model of cognitive orientation (Kreitler & Kreilter 1980), the deviation between physical and estimated duration will decrease as subjective orientation increases.

2. According to Jones and Boltz (1989), the duration of less structurally coherent musical excerpts will be both overestimated and less accurately estimated than more coherent experts.

3. Familiarity with style facilitates the anticipation of the future course of the musical excerpts. Combining this with the above hypothesis, we predict that as familiarity increases, duration estimates will become more accurate (cf. Block 1982).

3.1. Method

Prospective vs. Retrospective design

Investigations of perceived duration have used two main methodological designs (cf. Brown 1985, McClain, 1983, Hicks et al. 1976). In the *prospective* design, subjects are told in advance that they are to perform a duration estimation task, whereas in the *retrospective* design they are asked to estimate a certain duration from memory. In the prospective design, subjects focus their attention on “time per se” (*attention allocation model*, Thomas & Weaver 1975). We chose the retrospective design because, like Gibson (1979) and Jones and Boltz (1989), we doubt that time per se in perceivable. We also wanted to investigate typical musical listening behaviour in which the music itself and not its duration is the focus of attention.

Subjects

30 subjects with mixed musical experience (from professional musicians to lay-people) of age between 15 and 65 years participated: 15 in Expt. 1 and 15 in Expt. 2.

Stimulus Material

We presented excerpts of 30 seconds and 3 minutes of the following 20 peices:

- *Lost Nation,* Joe Lovano.

- *Prélude à l'après-midi d'un faune (Rondes de printemps*)*,* C. Debussy.

- String quartett No. 12, Op. 9 *(Moderato)*, J. Haydn.

- *The Indian Bamboo Flute (Sunset Raga),* Gour Goswami & Steven Gorn.

- *Messe de notre Dame (Kyrie),* G. de Machaut.

- *Parsifal (Vorspiel),* R. Wagner.

- *Suite Op. 29 (Ouverture),* A. Schönberg.

- *Free Jazz*, Ornette Colman.

- *Timeless,* John Abercrombie.

- *Aventures,* G. Ligeti.

- *Pipe Organ*, improvisation by Sri Chinmoy.

- *Das Wohltemperierte Klavier (Prelude D-major)*, J. S. Bach.

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- *Symphonie No. 3 "Liturgique" (Dies irae),* A. Honegger.
- *Miskima (Grandmother and Kimitake)*, Philip Glass.
- *Bashif Samai Asba'ayn, Jardín de Al-Andalus* von Eduardo Paniagua.
- *Discipline,* King Crimson.
- *Madanitche,* Kodda Cherif Hadria.
- *Donjo and Hora*, The Hungarian Gypsy Orchestra.
- *Flaschenachter,* Die Knödel.
- *Passacaglia Op. 1*, A. Webern.

Procedure

Each subject heard either 30 seconds (Expt. 1) or 3 minutes (Expt. 2) of each of the 20 excerpts in random order. For each except, they rated selected quasi-objective properties (tempo, predictability, variability, closure), selected subjective reactions (arousal, familiarity, pleasantness), and their level of attention. Each rating was made on a 7-point scale. They also estimated the duration of each excerpt in seconds or minutes. The order of items in the questionnaire was random and stayed the same throughout the study. The duration estimation item was near the middle of this order.

3.2. Results

In Expt. 1 (30 seconds), mean duration estimates did not differ significantly from actual duration, but individual estimates were widely spread (mean: 28.3 s; s.d.: 13.1 s). In Expt. 2 (3 minutes), durations were overestimated (mean: 4.9 min; s.d.: 1.2 min; see also figure 1).

Experiment 1: 30 seconds

A factor analysis produced two factors (Table 1). The structural variables correlating with estimated duration were variability and predictability.

Factor a, duration	Factor b
variability	preference
tempo	familiarity
arousal	attention
predictability	closure
duration	

Table 1: Factors (a, b) of Expt. 1.

On this basis, we combined the variables predictability and variability to produce a new variable called *perceived structuredness*. Figure 1 shows the deviations between physical and mean estimated duration for specific values of perceived structuredness. Here we see the most accurate estimations for medium structuredness (Expt. 1: left side), and the highest deviation (underestimation) for the highest perceived structuredness (Expt. 1).

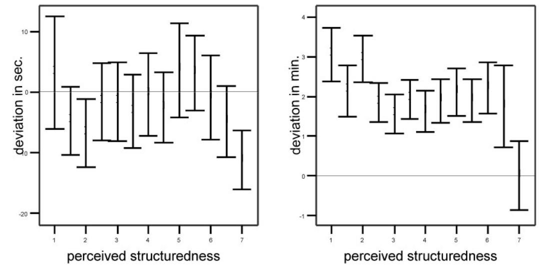

Figure 1: Deviation between physical and estimated duration against perceived structuredness. Left: Expt. 1 (30 sec.); right: Expt. 2 (3 min). Bars: s.d.

To test our Hypothesis 1 (above), we divided the ratings of variability and predictability into four equal quartiles (each with 75 data points) and calculated the mean perceived duration in each quartile (figure 2).

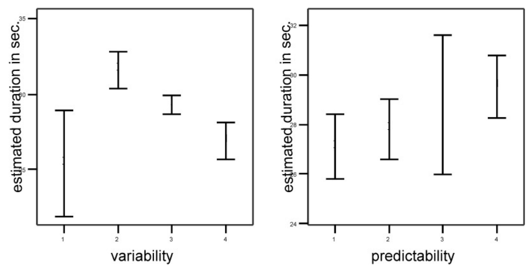

Figure 2: Expt. 1: mean duration estimates in seconds against quartiles of variability and predictability. 1 = first quartile, 2 = second quartile, etc. Bars: s.d. (75 data per point).

The relationship between variability and estimated duration was U-shaped. The two middle quartiles lead to most accurate estimations, first and fourth quartiles were associated with underestimations (1. quartile: mean = 25.43 s; s.d. = 3.53 s, 2. quartile: mean = 31.59 s; s.d. = 1.21 s, 3. quartile: mean = 29.32 s; s.d. = 0.61 s, 4. quartile: mean = 26.89 s; s.d. = 1.25 s). First and fourth quartile were significantly different ($t = 0.001$, $p < 0.01$). For the rates of predictability we obtained a linear relationship. High degrees of predictability were associated with most accurate duration estimates (1. quartile: mean = 27.10 s; s.d. = 1.33 s, 2. quartile: mean = 27.80 s; s.d. = 1.23 s , 3. quartile: mean = 28.80 s; s.d. = 2.82 s, 4. quartile: mean = 29.53 s; s.d. = 1.25 s). First and fourth quartile differed significantly ($p < 0.005$).

The second hypotheses could be confirmed. Highly predictable musical excerpts lead to more accurate estimations than excerpts of low predictability. But this seems not to be the effect of a low degree of variability, since duration estimates were most accurate for a medium degree of variability and a high degree of variability lead to underestimations (figure 3); so the effect of more changes being heard with less coherent events, which should lead to overestimations, did not occur.

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Familiarity was significantly correlated to predictability ($p < 0.05$) but not to estimated duration, as predicted in our third hypothesis.

Experiment 2: 3 minutes

A factor analysis produced two factors (Table 2).

Factor A, duration	Factor B
preference	familiarity
attention	tempo
closure	arousal
predictability	**duration**
variability	

Table 2: Factors (A, B) of Expt. 2.

The highest deviation between physical and estimated duration (~100%) could be seen with lowest rate of perceived structuredness and the lowest deviation with the highest degree of structuredness. But we obtained no significant correlation between perceived structuredness and perceived duration (s. figure 1).

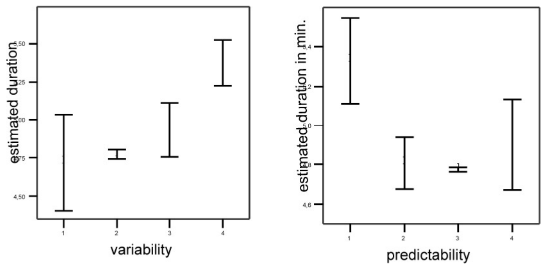

Figure 3: Expt. 2: mean duration estimates in minutes against quartiles of variability and predictability. 1 = first quartile, 2 = second quartile, etc. Bars: s.d. (75 data per point).

Regarding the variables for predictability and variability separately, results were quite different from Expt. 1. Again we divided the rates of variability and predictability into four quartiles (N = 75) and calculated the mean duration estimate for each (figure 4). This time we obtained a linear relationship between variability and perceived duration (1. quartile: mean = 4.72 min; s.d. = 0.32 min, 2. quartile: mean = 4.77 min; s.d. = 0.03 min, 3. quartile: mean = 4.93 min; s.d. = 0.18 min, 4. quartile: mean = 5.37 min; s.d. = 0,15 min) and a U-shaped curve for the relationship between predictability and perceived duration (1. quartile: mean = 5.33 min; s.d. = 0.22 min, 2. quartile: mean = 4.80 min; s.d. = 0.13 min, 3. quartile: mean = 4.77 min; s.d. = 0.01 min, 4. quartile: mean = 4.90 min; s.d. = 0.23 min). As predicted by the cognitive change model by Fraisse (1963) durations were overestimated for excerpts of a high degree of variability (figure 3).

Familiarity was significantly correlated to predictability ($p < 0.01$) but not to estimated duration, as predicted in our third hypothesis. In addition, a multiple regression for Expt. 2 revealed that duration estimates could be related to tempo ($p < 0.01$) and negatively related to attention ($p < 0.05$).

4. DISCUSSION

From the variables predictability and variability that we obtained by the questionnaire we calculated the variable *perceived structuredness*. Listener orientation – as defined in our theoretical background – was then stipulated as highest for medium structure and lowest for very high or very low perceived structure.

The first result was the large overestimation (100%) associated with a low degree of perceived structuredness in Expt. 2 (3 minutes).

We expected to find the lowest deviations for a medium degree of perceived structuredness, since according to the theory of cognitive orientation the human organism is used to events of medium complexity and should therefore be able estimate their durations correctly. Since the variable of perceived structuredness did not reveal significant results, we regarded the variables of variability and predictability separately and found in Expt. 1 a linear relationship between predictability and duration estimates and a u-shaped curve for the relationship between variability and duration estimates. In Expt. 2, results were the opposite, in that we found a linear relationship between variability and duration estimates and a u-shaped curve for the relationship between predictability and duration estimates.

So looking at the variables predictability and variability separately, we could assume, that in short events (30 seconds), subjects orient themselves more according to the amount of changes (variability), whereas in longer events the predictability is more important for cognitive orientation. This suggests that perceived complexity depends on the length of the temporal interval.

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