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Musically puzzling II: Sensitivity to overall structure in a Haydn E-minor sonata

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Abstract

Previous studies have suggested that listeners are insensitive to the overall tonal structure of musical pieces. In Part I of this report (Granot & Jacoby, 2011) we reexamined this question by means of a puzzle task using 10 segments of Mozart's B flat major piano sonata K. 570/I. As expected, subjects had difficulty in recreating the original piece. However, their answers revealed some interesting patterns, including (1) Some sensitivity to the overall structure of A–B–A' around the non-stable B section; (2) Non-trivial sensitivity to overall "directionality" as shown by a new type of analysis ("distance score"); (3) Correct grouping and placement of developmental sections possibly related to listener's sensitivity to musical tension; and (4) Sensitivity to opening and closing gestures, thematic similarity, and surface cues. In the current paper we further validate these findings by comparing the results obtained from a new group of participants who performed an 8-segment puzzle task of Haydn's E minor piano sonata Hob. VXI-34/I. The similarity of our results to those obtained with the Mozart sonata validates our methods and points to the robustness of our findings, despite the differences in the music contexts (composer and key), and despite some methodological caveats.

Keywords

concatenationism, global structure, local processing, musical puzzle, order effects, onata form, structural coherence

Introduction

In the first part of this work (Granot & Jacoby, 2011, hereafter referred to as "the Mozart study") we reported experimental results of a puzzle task using 10 segments from Mozart's B flat major piano sonata K. 570/I. The performance of 87 participants with varying degrees of musical training was examined. As expected, subjects had difficulty in recreating the

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original piece. However, their answers revealed some interesting patterns, including (1) Some sensitivity to the overall structure of A–B–A' around the non-stable B section; (2) Non-trivial sensitivity to overall "directionality" as shown by a new type of analysis ("distance score"); (3) Correct grouping and placement of developmental sections possibly related to listener's sensitivity to musical tension; and (4) Sensitivity to opening and closing gestures, thematic similarity, and surface cues. These results were based on four basic analytical tools that were fully described in our previous report. Here we highlight those aspects of the analysis which are novel and therefore of interest independently from the specific musical piece examined in that paper. Moreover, their novelty calls for some validation, which was defined as one goal of this follow-up study.

(1) *Histogram analysis*, in which we calculated a table $H_{i,j}$, where $H_{i,j}$ was the number of participants that had positioned the *i*th segment in the *j*th position. This type of analysis points to positions along the piece that may be privileged in terms of the placed segments. The actual values are then used to calculate the *p*-value of $p_{i,j}$, which is the probability that the actual $H_{i,j}$ would be larger than a value obtained if participants were placing the segments at random. A high *p*-value means that a cell was significantly more or less populated relative to a random permutation. In this analysis we also calculated the degree to which each segment was positioned in a chance manner (i.e., equally across all positions) by calculating the entropy of the segment histogram. The entropy can be seen as a measure of the "concentration" of the histogram using the following formula: $ent(j) = \Sigma_i (H_{i,j}/N) * \log_2(H_{i,j}/N)$.

(2) *Hyper-structure analysis* provided an examination of the degree to which listeners positioned the various sections in a very rough correct approximation reflecting the tripartite structure of the sonata form (A–B–A'). Rather than looking at the degree of correct placement in a high resolution of 10 (in the Mozart sonata) or 8 (in the Haydn sonata) possible segments along the sonata form, we "zoomed out" and examined the placement of the Exposition, development, and Recapitulation segments in the first, middle, and last thirds of three overlapping "windows."

(3) *Distance score analysis* was proposed as a novel statistical technique to quantify the distance between subjects' responses and the correct order. We applied two different distance scores: "Edit distance" and "Arrow of time distance." Intuitively, the *edit distance* of two permutations evaluates the number of editing operations (deletion, insertion, substitution) required to shift from the first permutation (the subject's proposed solution) to the second (the correct order). Under this definition, solutions closer to the correct order require fewer editing operations. The second measure of distance – the *arrow of time distance* – evaluates the degree to which permutations retain the correct order of the sequence, even if not in a complete manner. For example, in the solution 1–3–4–7–8–2–5–6, segment 3 is placed incorrectly in the second serial position, yet it is placed before sections 4–5–6–7–8, as indeed should be the case. This measure therefore may represent something of Cone's (1987) notion of "before" and "after." Using these distance measures we tested whether the distance between participants' permutations and the correct order differed significantly from the distance between participants' permutations and a random permutation on the one hand, and between participants' permutations and the order of the tracks they were presented with on the other. These analyses revealed that subjects' performance improves with musical training: the higher the number of years of musical training, the smaller the measured distance. Though this tendency was weak in comparison to the general difficulty that subjects had in

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recreating the original piece, this statistically significant tendency shows that subjects, especially those with musical training, do have some sense of musical form, albeit perhaps more coarse-grained than previously expected.

In order to test the validity of the methods of analysis developed for this study, and in order to examine whether results can be generalized across subjects and musical pieces, we used the same task and analysis methods with a different group of subjects, and a second musical piece written in the minor mode. The selected piece was the first movement of the E minor sonata Allegro no. 34 Hob. VXI by Haydn, published in London in 1784. The minor mode of the first theme presents a clear contrast with the second theme on the parallel major, thus serving as a powerful structural cue not found in the major mode Mozart sonata.

Methods

Participants

Eighty-two participants (34 males, 48 females; aged 19–61) with a wide range of formal musical training participated in this experiment. Thirty-one of the participants had 7 or more years of formal musical training ($M = 12.0$, $SD = 5.9$), six had 4–6 years of playing an instrument but never studied theory, and the remaining 45 participants had very little musical training – usually just music classes taken in elementary school ($M = 1.33$, $SD = 1.65$).

As in the Mozart study, pianists and composers who were expected to know the test piece well were excluded a priori from this study, as were participants who self-reported familiarity with the piece. About half the participants performed the task as part of the requirement for their music cognition course and the rest were paid approximately $12 for their participation.

Musical stimuli

Table 1 presents the structure of the 1st movement of the E minor sonata Allegro no. 34 by Haydn. Like the Mozart sonata, it follows the traditional sonata form quite clearly and has mostly distinct sections, each ending in a rest. However, even more than the Mozart sonata, these sections are all based on a single theme creating a monothematic sonata, typical of many Haydn pieces. This focuses attention to the contrasts between the major and minor sections of the piece, rather than to thematic contrasts.

We used Sound-Forge 5 to edit the recording of the piece performed by Alfred Brendel (as found on Philips CD 416-643-2 "Haydn: 11 Piano Sonatas, Fantasia, Andante, Adagio"). The total duration of the recording is 2'55, omitting the repeat of the Exposition. No manipulations were made to the recording (including no use of fade-in or fade-out) other than cutting it into 8 sections.

Task and procedure

The experimental procedure was very similar to the Mozart study. Participants received a disc with 8 tracks separated from each other by 2 seconds of silence. All discs had the same intentionally designed order. As in the Mozart sonata, this order included the modulatory bridge section of the Exposition as the first track, presumably making it less appropriate as a first section in a piece written within the Classical style.

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Table 1. Haydn Hob.VXI-34/I in E minor: Structure of the sonata: allegro: 1st movement.

Function in sonata form (mm. = measure no.)	Track on disc (duration in seconds)	Initial harmony		Final harmony		Features possibly relevant to perception of local and global structure
		Local harmony	Global function	Local harmony	Global function	
Exposition: 1st group. mm. 1–8	5 (11)	em	I	B	V	Arpeggio of the tonic chord in the bass–responded to by a motive of a 3rd – the main motive across the entire piece
Exposition: bridge. mm. 9–29	1 (28)	em	I	D	V/III	Begins like the 1st theme but then modulates to G major heightened by *f* and 16th notes, leading to an emphatic cadence on D
Exposition: 2nd group includes 4 measures of closing theme. mm. 30–45	7 (23)	G	III	G	III	Similar in many aspects to the 1st theme. Ends on a short closing theme to be expanded in the recapitulation
Development: 1st part. mm. 46–50	4 (07)	E	I major	E	I major	Echoes the first four measures of the 1st theme but in major mode
Development: 2nd part. mm. 51–78	3 (35)	C	VI	B	V	Motive derived from the bridge. Diminished chords and appoggiaturas up to a pseudo Organ point on B
Recapitulation: 1st theme 1 + bridge mm. 79–94	8 (21)	em	I	B	V	Mesh of first theme and bridge of the Exposition, all on the tonic E minor key
Recapitulation: 2nd theme mm. 95–108	6 (21)	em	I	B	V	Expanded version of the 2nd theme of the Exposition on the tonic E minor key
Recapitulation: closing theme mm. 109–127	2 (25)	em	I	em	I	Expanded version of the closing theme of the Exposition on the tonic E minor key

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Table 2. Haydn – Histogram of segment placements and entropy values.

Position	1	2	3	4	5	6	7	8	Entropy
Theme 1(E)	20.7%	9.8%	15.9%	17.1%	11.0%	13.4%	7.3%	4.9%	2.8821
Bridge (E)	28.0%	24.4%	6.1%	18.3%	8.5%	7.3%	2.4%	4.9%	2.6276**
Theme 2(E)	4.9%	12.2%	14.6%	12.2%	11.0%	17.1%	22.0%	6.1%	2.8793*
Development1	4.9%	11.0%	17.1%	15.9%	29.3%	14.6%	3.7%	3.7%	2.6928**
Development2	3.7%	6.1%	20.7%	12.2%	15.9%	17.1%	13.4%	11.0%	2.8568*
Theme1+Bridge(R)	25.6%	12.2%	12.2%	6.1%	11.0%	17.1%	9.8%	6.1%	2.8487*
Theme 2(R)	9.8%	12.2%	9.8%	15.9%	8.5%	8.5%	32.9%	2.4%	2.7111**
Closing (R)	2.4%	12.2%	3.7%	2.4%	4.9%	4.9%	8.5%	61.0%	1.9695**

*$p < .05$; **$p < .0001$

All other aspects of the task and procedure were identical to those used in the Mozart study.

Analysis

All analysis methods are identical to those described in the Mozart study.

Results

As in the case of the Mozart sonata, only two musically trained participants provided the full puzzle solution. Interestingly, one participant with no musical training at all provided a nearly complete solution (7–8–1–2–3–4–5–6, i.e., erroneously beginning with the last two segments of the original sonata followed by all other segments in the correct order). Nonetheless, most of the participants concatenated correctly only 2 or 3 segments.

Histogram analysis

Figure 1 is a visualization of Table 2. Positions along the piece appear on the Y axis, and segment numbers appear on the X axis. All correct placements are found on the diagonal. Colors represent the % of participants who placed a specific segment in a specific position scaled to the maximum number of participants in all cells (i.e., 61%). The higher the percentage, the brighter the color. For example, 61% of the participants placed the ending section of the piece (segment 8) in the last position (hence a correct placement). However, only 20.7% position the opening theme (segment 1) in the first position. Hence we can discuss two aspects of the data: The degree to which specific locations along the piece are "privileged", (show a high percent of correct or incorrect placements), and the degree to which a specific segment tends to be placed equally across all locations (entropy). These two aspects are, of course, not independent.

As in the Mozart study, the last segment was positioned correctly far above chance level. In fact, in the Haydn piece, as seen in Table 2 and in Figure 1, this was obtained by the majority of the participants (61%, *p*-value close to 1). The opening theme (segment 1) was also positioned in the correct serial position above chance level (*p*-value .99), but this was a weaker effect (20.7%) than that seen in the Mozart study (29.9%). This relative weakness is also evident in the entropy value of segment 1, which is relatively high and on the boundary of chance level (*p*-value ~.07). As in the Mozart study, participants tended to place erroneously the bridge section of the Exposition (segment 2) at the beginning of their proposed solutions (*p*-value close to 1). This may be partially explained by the fact that the bridge section of the exposition was the

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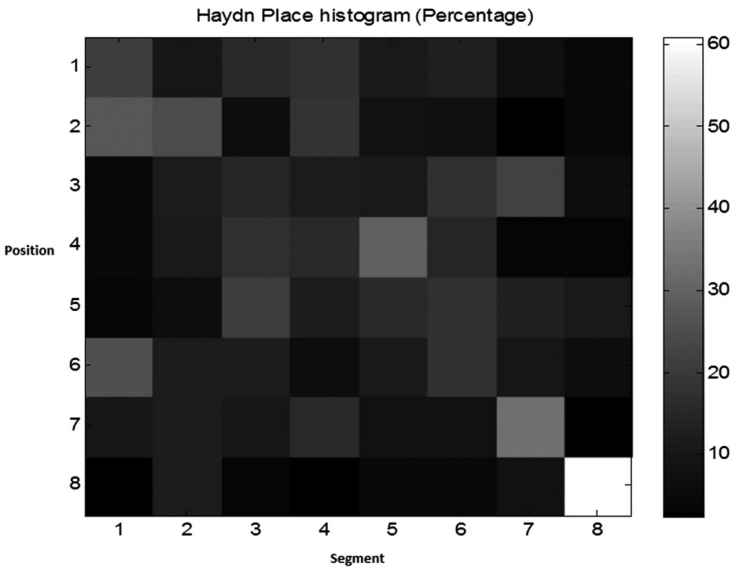

Figure 1. Haydn histogram placement.

first segment heard on the CD. But participants had an equal tendency to place in the first serial position, segment 6, which is a shortened and fused version of the first theme and the bridge as they appear in the recapitulation. This suggests that, despite the power of the order effect, other, more musical considerations may also influence participants' selections.

Another segment that was placed correctly significantly above chance level (32.%, *p*-value of entropy close to 1) was the next-to-last section (2nd theme of the recapitulation), which was the only section that did not end in the original Haydn piece with a clear pause, and therefore provided surface cues for conjoining it with the successive concluding section. Interestingly, the first part of the development (segment 4) also shows an extremely low entropy value ($p < .01$). It was mostly placed in the fifth serial position. Although this is technically an incorrect positioning, it does indicate sensitivity to the notion that the developmental sections should be placed at the middle of the piece. This sensitivity is also evident in relation to the second part of the development (segment 5), albeit in a somewhat weaker form ($p = .024$).

Hyper-structure analysis

The hyper-structure analysis of the Haydn piece followed the outline described in the Mozart study, with the following three windows: first window (positions 1–4), middle window (positions 3–6), and last window (positions 5–8).

Results (Table 3) are remarkably similar to those obtained in the Mozart study: the Recapitulation segments were placed significantly higher than chance in the correct last window ($p > .999$) and significantly not placed in the wrong first and second windows. The Development sections were placed, as in the Mozart piece, at a significantly higher than chance level in the correct middle ($p > .999$) window. In the Exposition, a similar pattern appears as in the Mozart study: positioning the Exposition material in the first correct window is significantly high, positioning it in the third window is significantly low, but positioning it in the second window is not significantly low.

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Table 3. Haydn – hyper-structure across 3 overlapping windows.

	Exposition	Development	Recapitulation
Window 1 [a]	151[b] (1.000) *	75 (0.1363)	102 (0.0008) *
Window 2	125 (0.6492)	117 (1.0000) *	86 (0.0000) *
Window 3	95 (0.0000) *	89 (0.8978)	144 (0.9995) *

[a]Window 1 = segments 1–4; Window 2 = segments 3–6; Window 3 = segments 5–8
[b]*N* segments found in the window & (*p*-value)

Table 4a. Haydn: Edit distance score as a function of musical training.

Group (years of training)	*N*	Mean distance to Mozart	Mean distance to original CD order	Mean distance to random permutations
1 (0)	26	5.81*	6.42	6.35
2 (4 ≥ Y > 0)	22	5.45*	6.64	6.36
3 (9 ≥ Y > 4)	14	5.07**	6.21	6.35
4 (Y > 9)	20	4.55***	6.25	6.35

*$p < .05$; **$p < .01$; *** $p < .001$

Table 4b. Haydn: Arrow of time distance score as a function of musical training.

Group (years of training)	*N*	Mean distance to Mozart	Mean distance to original CD order	Mean distance to random permutations
1 (0)	26	12.81	14.73	13.98
2 (4 ≥ Y > 0)	22	9.55*	14.82	13.91
3 (9 ≥ Y > 4)	14	10.36*	13.79	13.92
4 (Y > 9)	20	9.50**	14.8	13.90

*$p < .05$; **$p < .01$

Distance-score analysis

As in the analysis of the Mozart results, we first divided our participants into four groups of roughly equivalent size based on their musical training. Group 1 consisted of 26 participants with no training at all; Group 2 consisted of 22 participants with less than or equal to 4 years of training; Group 3 consisted of 14 participants with more than 4 and less than or equal to 9 years of training; and Group 4 included 20 highly trained musicians with over 9 years of training.

As seen in Tables 4a and 4b and in Figures 2a and 2b, the distance score of the correct order diminishes with musical experience. This relationship is less consistent in the arrow of distance measure (Figure 2b), which shows no difference between listeners with little musical training (> 0 and < 4 years of training) and those with over 9 years of training. In addition, we can show that these results are meaningful by comparing them to a different subdivision of the group, according to gender rather than musical training (males $N = 34$; females $N = 48$). As in the Mozart piece, the distance arrow scores for both males and females are significantly different from a random permutation (males: mean = 5.29, *p*-value .001; females: mean = 5.27, *p*-value .004) and no different from each other.

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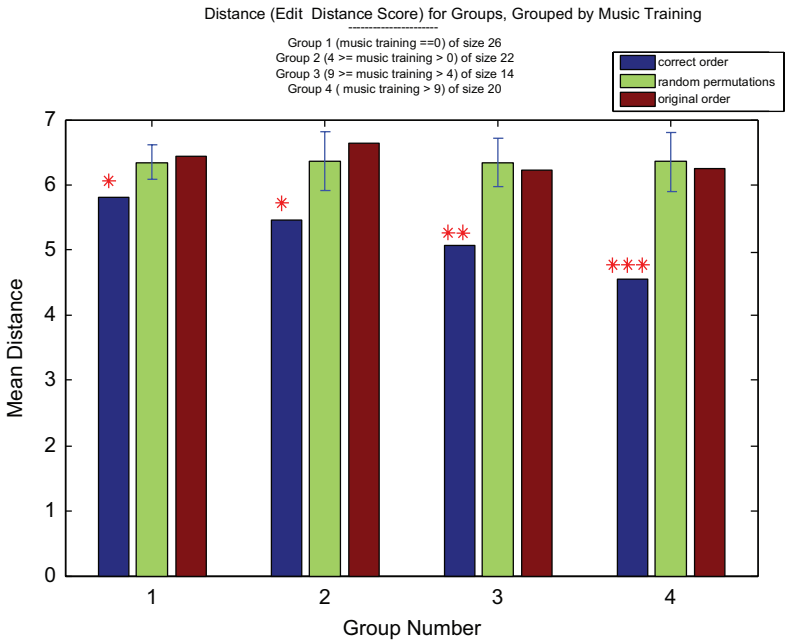

Figure 2a. Haydn distance scores.

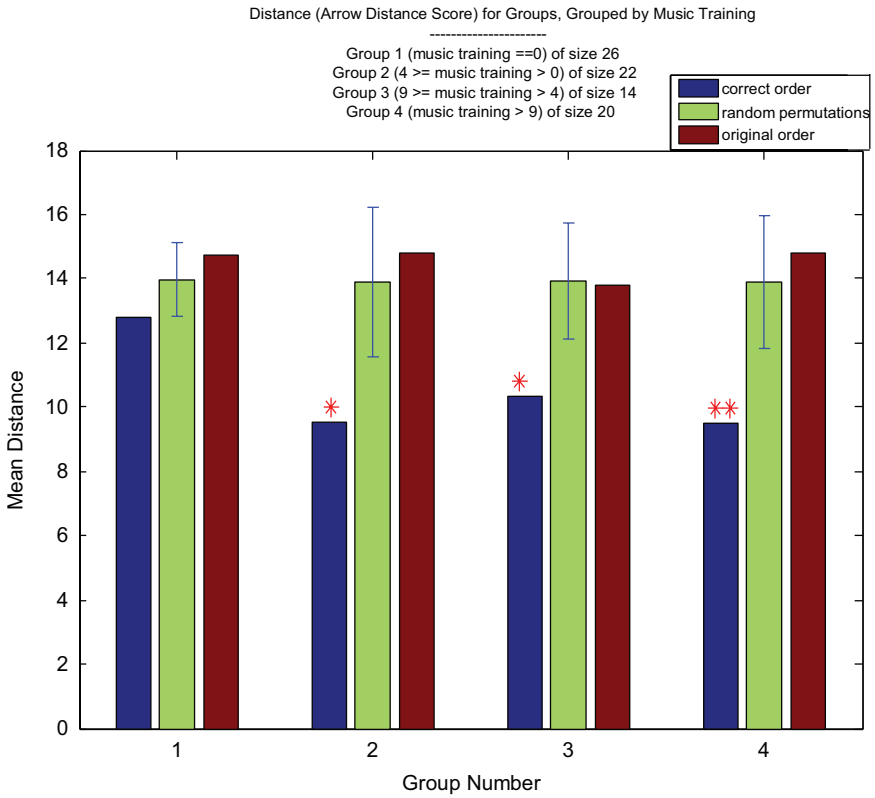

Figure 2b. Haydn arrow of time scores.

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Discussion

Most of the results in the Haydn sonata parallel those found in the Mozart sonata study. On the most general level, the placement of sections is not random. This is first and foremost true of the last segment, clearly identified as the closing segment. The opening section was harder to localize as compared to the opening theme in the Mozart sonata. This may have resulted from a number of factors. First, there is little in the way of rhetorical cues that define this theme as an opening one. There is no clearly developing melody, but rather motivic elaboration of the kernel of the 3rd and its inversion the 6th. The theme "sneaks in" through a quiet arpeggio in the bass and ends too briefly on the dominant after only 8 measures. Interestingly, participants chose to begin their proposed piece with the first theme of the Recapitulation, which is an expanded version of the very short first theme of the Exposition. In fact, they chose this section from the recapitulation more often than they chose to begin with the correct opening material, or with the incorrect bridge material that was presented to them first in the disc. Moreover, they rarely positioned in the first position any other segments: neither unstable segments like the second part of the Development, nor harmonically inappropriate segments in major mode (the first part of the Development or the second theme).

Importantly, as in the Mozart piece, neither of the developmental sections was placed at the beginning or ending of the piece. Moreover, the developmental sections tended to be paired together — as often as, for example, sections not ending on a pause. Also consistent with the Mozart study was the fact that not only were the developmental sections placed significantly higher than chance in the correct rough position along the piece (i.e., the middle), but both Exposition segments and Recapitulation segments were placed roughly correctly.

Finally, as in the Mozart sonata study, musical training had a significant effect on the accuracy of the provided solutions. The higher the number of years of musical training, the further the solution was from a random solution or from the original order presented on the disc and the closer to Haydn's original piece.

General discussion: The Mozart and the Haydn sonata studies

Sensitivity to global structure: Symmetry and tension rather than harmony

Our two studies show that if there is anything cognitively privileged about the sonata form, it is not found in its tonal design or process but rather in its overall A–B–A' organization around the non-stable and tense B section. In both the Mozart and Haydn sonatas, participants showed sensitivity to the non-stable developmental sections, manifested in their avoidance of placing these sections at the beginning or ending serial positions of their proposed solutions, and in pairing both developmental sections together. Moreover, in both experiments, the paired developmental sections were placed roughly at the middle of the piece at an above chance level. This is consistent with the idea of a convex contour of tension, proposed by a number of theorists as one important defining feature of the sonata form (Cohen, 1971; Huron, 2006; Kamien, 1988). The fact that the same result was obtained in two very different sonatas played by two different performers, and by two different participant groups, strengthens this conclusion.

Note that the developmental sections were paired at an above chance level despite the clear pause at the end of the first part of the Development. This is in contrast with thematically parallel sections in the Exposition (which serve as the basic material to be developed) that are not paired at an above chance level, suggesting it is not the thematic material per se that drives the pairing but rather its developmental character. This manifests itself in fast motion from one

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tonal center to another, minor mode colorizations, higher levels of dissonance (e.g., many seventh chords), higher density, increased dynamics and tempo, all of which are further highlighted by the performers in both recordings. In a word – listeners are sensitive to musical tension. This presumed sensitivity to musical tension is consistent with the centrality of tension as one of the most fundamental concepts in the analytical, aesthetic, and psychological discourse on music.

Positioning the tense sections roughly at the middle of the musical structure, creating a convex contour of tension, seems to be a "natural" selection, as described in one of the participants' free comments on how the puzzle was solved: "According to my logic, one should begin and end in a calm way, such that the most intense section should be in the middle." Convex pitch contours were found to be more prevalent in a wide range of melodies (Huron, 2006) as compared to concave or linear contours. Convex contours are also prominent in the style of Palestrina counterpoint striving for calm expression (Cohen, 1971). In the compositional rules underlying Palestrina's style, the highest tone should appear once, neither at the beginning nor at the end of the melody. More generally, tension creating events such as dissonance, melodic jumps, rising contour, and short inter-tone intervals should be prepared and arrived at gradually and should also be resolved once they have been presented.

In summary, two strong non-orthogonal hypotheses emerge from these data. First, a symmetric A–B–A order of sections will be preferred over other possible orders such as A–A–B or B–A–A. This, however, may be dependent on the size and complexity of each unit and the degree to which they share or differ in musical content. Second, the A–B–A preference may be driven in part or entirely by the contour tension, such that if B is the tense section, an A–B–A order will be preferred, whereas if A is tense, A–A–B will be preferred over A–B–A.

Sensitivity to rhetoric cues and thematic relationships

A consistent finding was listeners' ability to place well above chance the ending sections of the sonata and, to a somewhat lesser degree but still clearly above chance level, the opening sections of the sonata. This suggests that listeners were sensitive to rhetorical cues such as cadential formulae or unison textures that were probably supplemented by performance cues (the analysis of which extends beyond the scope of this paper) such as *ritardandi*, indicating closure. Points of closure are of utmost importance for clarity of structure. Hence, in Western as well as in many non-Western musical cultures, these points are often marked by stereotypical patterns (Huron, 2006). In contrast, opening phrases are by definition much less constrained.

Our analysis also suggested sensitivity to thematic similarity and elaboration. This was also seen in listeners' free explanations about how they approached the task. About 32% of the participants in the Mozart experiment and 19% of the participants in the Haydn experiment mentioned using thematic similarity as a strategy. This difference probably reflects the monothematic nature of the Haydn piece. Here are two typical quotes, indicating how the same strategy could lead to two very different solutions: "I tried to group together similar tracks and then tried to organize them"; "I categorized the tracks into 3 groups and then I started playing around with them, making sure that there would not be two successive tracks from the same group." Clearly, the second quote is more consistent with the Classical compositional style, in which contrasts rather than similarities are often juxtaposed. Rhetorical cues such as repetition, contrast, amplification, progression, and conclusion have also been proposed by Lalitte et al. (2009) as a set of "functions and strategies" for arranging musical ideas into a global structure. Our study concurs with their finding that listeners are sensitive to these cues and may

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have some perception of the global structure on the basis of these cues rather than on the basis of tonal structure. As Meyer (1991) notes, relationships of physical similarities among motives, textures, or timbres are more "natural" as compared to syntactic or functional relationships, which require at least wide exposure to pieces written under these syntactic constraints. A more complete analysis of the ordering of similar or developing motives (beyond the pair analysis presented here) is required in order to expose any cognitive principles underlying the possible successive arrangements of these variants as a musical piece unfolds in time.

Insensitivity to global harmonic structure

In contrast with the sensitivity to harmonic instability, rhetorical cues, and melodic similarity, listeners did not show sensitivity to global harmonic considerations. As in Karno & Konečni (1992), participants were influenced more by order effects than by harmonic considerations. Thus, they often placed the bridge section, presented to them first on the disc, in the first serial position despite the fact that in its very first measures there is a clear modulation from the main key of the piece to a secondary tonality (the dominant or parallel major). This was equally true of musically trained as of untrained participants. Furthermore, only 11.5% of the participants who listened to the Mozart sonata followed the bridge section of the Exposition with its harmonically correct resolution. This performance, which was at chance level, was equally poor in the musically trained and untrained participants. This suggests, as Tillmann, Bigand, and Madurell (1998) previously found, that even the musically trained participants could not integrate the local events into a higher-level global harmonic structure presumably necessary to sense the ending cadence of the bridge as leading to a single harmonically congruent solution. Only when the harmonic cue was supported by the change from the minor to the major mode, as in the Haydn sonata, did the performance of musically trained participants rise to an above chance level (35.5%).

The influence of musical training

Despite the fact that subjects' responses were evidently not random, very few – only two in each experiment — provided the full puzzle solution. This may be surprising given the fact that there were 20 participants in each experiment with 9 years or more of musical training. Moreover, many of them reported noticing explicitly that they were presented with a sonata form and used this to guide their performance on the task. A similar dissociation between explicit identification of the musical piece as a sonata form and the failure to relate its various sections to the functional sections of this form was also reported in Berz and Kelly (1998). This result may reflect on the methods we use to teach our students about the sonata form, possibly indicating too much theoretical training and too little auditory training.

Nonetheless, using new statistical tools we could show that the number of years of musical training does influence the correctness of the proposed solutions, such that the higher the number of years of musical training, the closer the groups' solutions to the correct order. Although editing distance scores have already been used in several contexts (e.g., Orpen & Huron, 1992), they were previously used to detect similarity between melodies and not as a measure of the quality of the solution for groups of participants. In addition, the arrow of time distance score is totally novel, encompassing the notion of a forward flow of music such that rather than focusing on exact placement of segments we focus on the notion of *earlier* and *later*.

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Some methodological issues

In this study we focused on what listeners perceive and respond to, rather than what they do not. Given previous findings, we hypothesized that listeners would not be very successful at reconstructing an entire 10- or 8-section sonata. Therefore, we examined emergent patterns rather than a priori hypotheses. This in turn evidently results in some relatively weak post hoc explanations that will need to be further examined. In addition, the puzzle task itself has been questioned as being anti-ecological. However, our findings did show in all analysis methods significantly different results from the null hypothesis of random answers. Therefore our findings support the notion that some insights can be gained from this methodology. In the following, we address two other more specific methodological concerns.

1. The two-second gap. One could argue that the 2-second gap disrupts the natural flow of the music, possibly imposing a more local rather than a global type of processing. It is important to stress that the problem is not one of memory decay per se. Models of auditory processing postulate the existence of a temporary transient sensory buffer, which spans at least 2–4 seconds according to Cowan (1984), allowing for the integration of information across this gap. Rather, it is on a higher level that disruption is possibly created by stressing closure. In fact, composers were very conscious of the power of silence to create closure, with numerous examples of "bold" harmonic shifts or modulations ventured across a pause. This was true not only of the pre-Classical style, as evident in the works of C. P. E. Bach and Scarlatti, for example, but also of the full-blown Classical style as seen in Mozart and Haydn. Nevertheless, there are also numerous examples in which conductors and performers use a dramatic long pause only to heighten the expectancy for the continuation. So, silence per se should not necessarily inhibit the sense of incompleteness. This is clearly evident in our analysis of pairs of sections showing that the two sections of the Development tend to be paired even though the first part of the Development (in both sonatas) ends on a complete local (though not global) cadence followed in the original piece by a pause.

This is not to say that listening to the fragmented sections in the current study is equivalent to natural music listening. The analogy of a jigsaw puzzle with 8–10 large pieces — each of which contains a coherent, even if incomplete, part of the scene is pertinent here. We can restructure these pieces since they fit surface features of color, texture, and contour as well as constraints imposed by the overall content and structure. No one will claim that reconstructing a jigsaw puzzle is similar to natural viewing of a visual scene. Nonetheless, one may still learn from how people approach this task about perceptual and cognitive constraints and strategies relevant to how we process information.

2. Using a single order on the CD. We opted to present all participants with a single order, in which the first section on the CD was chosen to be the non-stable section of the bridge of the Exposition. Order effects under this condition would be especially strong, indicating that the order of presentation outweighs important tonal and thematic musical considerations. This was indeed borne out, and was surprisingly evident in both musically trained and untrained participants, although to a lesser degree in the musically trained. Using a single order on the CD also facilitated some of the analyses presented in the distance score analysis summarized below. For example, in the Mozart piece (see Figures 3a, 3b in the Mozart study) the mean distance of the most trained musician's group to the order presented on the CD was significantly large (with respect to random permutation), showing at least some evidence to support the claim that the order on the CD was especially far from the correct order, and therefore using it has merit.

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In order to test more directly the results that showed a strong order effect, we compared the relative frequency of placing in the first location (i.e., the beginning of the proposed solution) of the Mozart proposed solutions, the bridge section of the Exposition versus the bridge section of the Recapitulation. These sections in the Mozart sonata are nearly identical (except for an extra step in the harmonic sequence in the bridge of the Exposition, which leads to the V/V rather than V). Whereas the bridge of the Exposition was presented as the first track on the disc, the bridge of the Recapitulation was presented as the eighth track. Nearly 30% of the participants positioned the bridge of the Exposition as their opening track, as compared to only 9.2% who positioned at the same location the nearly identical bridge of the Recapitulation. Comparison of these relative frequencies using Fisher's exact test indicates that this difference is significant ($p < .05$), clearly confirming the order effect.

3. The participants. Finally, one cannot dismiss the social and cultural context in which our listeners are immersed: with access and exposure to a multitude of musical styles, most of which are not necessarily based on large-scale forms or even Western tonal syntax. We will never know whether these same findings would have been found in 18th-century listeners. One may hypothesize that listeners (those privileged ones of the aristocracy) who were exposed only to "new" 18th-century pieces could develop a higher sensitivity to deviations from the tonal syntax even in large-scale pieces. On the other hand, it must also be remembered that the notion of a deeply immersed attentive listener is more reflective of the 19th-century concert-goer than of 18th-century concert and opera audiences, who divided their time and attention between the music and social encounters (Weber, 1997). What might have been very different was the musical education of musicians, who were highly trained in improvisation and playing by ear rather than from the score (Moore, 1992).

Conclusions

The ability to categorize sections as stable versus unstable, sensitivity to rhetorical cues of opening and closing gestures, and sensitivity to melodic relationships seem to underlie the performance in our two puzzle studies. Importantly, these three factors together were sufficient to lead participants to "recompose" structures which, although different in detail, share the general A–B–A' structure in an above chance manner. As in previous studies, we found no evidence for integration of the harmonic information into a global structure. Therefore, the conceptually appealing idea that one can recursively apply the rules of harmonic syntax to larger and larger units may not be perceptually valid — at least for the large majority of listeners, both musically trained and untrained. Somewhere along the increasing scale of units, the analogy Meyer (1956) and others have so elegantly proposed breaks down. Interestingly, Meyer himself "confessed" in his keynote speech "A Pride of Prejudices; Or, Delight in Diversity," published in *Music Theory Spectrum* (1991) that he, like others, has erroneously extrapolated principles from a low to a high organizational level. In that paper, he proposes the "law of hierarchic discontinuity," according to which different organizational principles apply to different structural levels and to different parameters. Nonetheless, the path drawn in Western tonal music of extending recursively the same rules of hierarchy from the expressive microtonal deviations which embellish the tones to which they are applied, through chromatic embellishing tones, up to whole sections viewed as subordinate (hence embellishing), to more central or stable sections (e.g., Lerdahl & Jackendoff, 1983; Meyer, 1956), is one manifestation of the possibility art provides of extending in the making, principles from the perceptual to the conceptual realm. This may

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in fact be a hallmark not only of art but of human thought and creativity as manifested, for example, in conceptual metaphors which transfer experiences and relationships in the real physical world to more abstract realms. Finally, we should remember that art is not necessarily about what we can see or hear, but rather about what we can imagine.

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