On retrograde

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Critique of Zatorre, Halpern, and Bouffard (2010) study

Zatorre et al (2010) investigated musical abilities with retrograde, a task borrowed from polyphonic technique. Whereas polyphonic melodic thinking had passed its heyday in the XVIII century, polyphony is still a common practice among highly-trained classical musicians, particularly clavier players. Polyphony involves a simultaneous interaction of several melodic lines discussing a melodic theme. The melodic theme (the subject of polyphonic composition) can be variously transformed, for example, it can be "bent" in tonal answer by forces of phenomenal tonal gravity; it can be inverted (all melodic intervals change their direction), augmented, diminished, and reversed in time (retrograde). In the exceptionally rare cases, a melodic theme is simultaneously inverted and reversed in time (inversed retrograde).

Considering Zatorre et al intention to investigate melodic processing, their choice of melodic stimuli—retrograde—is puzzling. Musical practice shows the extreme rarity of retrograde: A cursory analysis of polyphonic music that is most popular among professional musicians (Two- and Three-Part Inventions, two books of Well Tempered Clavier, and Art of Fugue by J. S. Bach, and 24 Preludes and Fugues by D. D. Shostakovich) demonstrate that retrograde, figuratively speaking, is as rare in music as palindrome in poetry. In other words, Zatorre et al decided to explore an exception in melodic perception. They do not explain why this unusual kind of melodic stimuli is important for our understanding of melodic cognition, thought they do emphasize the importance of tonal scale during perception of melodic transforms.

The Zatorre at al's paper contains several references to mental practicing by musicians, but it is not clear how these references are related to perception of retrograde. The ability to remember a melody is common among the majority of population (Dalla Bella, 2007). In comparison, professional musicians are trained to recognize not just a melody but the melody's transformations in such complex musical structures as the fugue and the sonata allegro form. The choice of retrograde, this particular kind of melodic-temporal transformation, which is barely (if ever) used by the majority of even highly-trained musicians, makes the authors' reference to mental practicing by professional musicians somewhat irrelevant. Retrograde, in general, is not part of professional musical practice, as compared to some common melodic transformations such as tonal answer (which creates a conceptual analogue to a rotated "object" thanks to changes in melodic intervals and the influence of tonal force field) and inversion (systematic reversal of all melodic intervals of a melody or "mirroring"). Musical expertise on its own does not warrant good skills in melodic transformation, and such specific ability as Absolute Pitch can actually undermine these skills (Miyazaki, 2004).

The truly convincing argument for the studying retrograde is related not so much to music as to language and numerical thinking was presented in the authors' comparative analysis of

processing of retrograde and processing of inversed strings of digits and words. This comparison between the exception in melodic thinking (retrograde) and exception in linguistic thinking (reversed string of words in a sentence) provides interesting insight. This part of the paper would have benefited from additional references to other relevant studies (for example, Dehaene, 1997; Coull & Frith, 1998; Patel, 2008, 2009; Fedorenko, Patel, Casasanto et al, 2009; Dehaene, Nakamura, Jobert et al, 2010).

In contrast to the references to studies in the linguistic and numerical tasks, the authors' references to mental rotation (in relation to melodic transforms) appear as problematic because of the choice of melodic stimuli. Zatorre et al propose that melodic processing is related to mental rotation. For such proposal, the choice of retrograde is particularly unfortunate.

First, there is no conceptual analogue of retrograde among the 3-D rotated objects in Shepard and Metzler (1971) study. Whereas the most popular melodic transformation from polyphonic technique (inversion and tonal answer) can be "visualized" as conceptual simulacrums to the 3-D rotated objects, retrograde is an exception because its melodic pitch-set is reversed in time. This creates and interaction of temporal and tonal transformations. Perhaps the authors' choice of retrograde was influenced by the results of Cupchik, Phillips, and Hill (2001) study, which found that accurate discrimination of retrograde transformations predicted accuracy on the mental rotation task. However, the results of Cupchik et al also showed that retrograde transformation was better differentiated than inversion, namely, that the correct rejection of imprecise inversions was negatively correlated with the spatial task, and the positive recognition of inverted targets was unrelated to spatial rotation. This finding contradicts the results of Dowling's extensive research in melodic contour. Moreover, our analysis of melodic stimuli in Cupchik et al study shows that the stimuli for retrograde represent rather a task on pitch-set recognition than on perception of inverted melodies (the computer-generated sequences of few tones do not make a coherent melody, and some retrograde are just 3-tone-long). The choice of the familiar melodies in Zatorre et al study only strengthens the case for pitch-set recognition in their retrograde.

Whereas there are problems with the authors' use of retrograde as a conceptual parallel to visuo-spatial processing, the understanding of retrograde as a task on pitch-set recognition can be useful for comparative studies in processing of rearranged elements. Thus the authors' comparison of retrograde (as a string of independent tones) with a sting of reversed words and a string of reversed digits is wonderfully appropriate. Here comes the strength of Foster and Zatorre statement that the generation of activity in the anterior intraparietal sulcus during listening to melodic transformation may support "a general capacity for transformation and comparison of systematically related stimulus attributes." This statement needs a parsimonious interpretation, namely, that the words "systematically related stimulus attributes" are referred to the sense of tonality for a pitch-set and not to the sense of a melodic shape. And it is indeed hard to see what exactly allows Zatorre et al to compare their melodic task (reversal of tones in time) with mental rotation of the "continuous" 3-D objects. The inevitable questions arise: How the discrete tones in retrograde transform (as a string of tones) can be compared to a "wholeness" of

a 3-D object? What elements of the 3-D object are analogous to the tones in retrograde? The authors' statement about "stimulus attributes" provides little help for such analogies.

Mental rotation is a routine task, whereas retrograde is a rare exception. Tonal answer is a simple task, inversion is much more difficult but still bearable because it preserves temporal aspect (rhythm). It is not an accident that retrograde did not become a popular kind of melodic transformation in Baroque polyphony. The difficulty of this melodic task is extreme because retrograde affects the two main musical dimensions of tonal chronotope—tonal force field and psychological time. To make a conceptual comparison between melodic shape and a3-D object, perhaps it would have been more appropriate to select those melodic transformations which are routinely studied by the musicians for their performing practice and which are available to non-musicians in popular music. The easiest (and most common) melodic transformation is tonal answer in which melodic intervals are changed due to the melody's motion within the tonal system of reference. In our study in melodic rotation, a melodic transformation that involved change of melodic intervals only was named "bent" contour and was explained as a conceptual melodic equivalent of a slightly rotated 3-D geometrical object which sides appears (due to rotation) as changed in size. Foster and Zatorre used (unintentionally) a similar transformation as an imprecise variant of melodic transposition (transposition itself is not a melodic transform). Their results showed that perception of "bent" melodic contour generates activation in anterior intraparietal sulcus. This is an unquestionable confirmation of our prediction of the parietal activation during perception of altered melodic contour.

Next to other melodic transforms, retrograde is particularly difficult to recognize as a transformed melodic shape because in a reversed melody tonal transformation is accompanied by temporal transformation. In music, the arrow of time is critically important, and when a given pitch set is rearranged, this can completely transform a melodic image. Even when the pitch-set is not rearranged but has a different rhythm (different relative durations of tones), this can entirely change a melody. In retrograde—if it is not a melodic palindrome—the listeners face two simultaneously-presented cognitive tasks which solution requires application of both tonal and temporal templates. This is an overwhelmingly difficult mental operation that demands an exceptional cognitive control. This is why retrograde is not part of general musical practice.

Zatorre et al conclude their paper with a startling philosophical excurse in which they present the theoretical foundation for the hypothesis of supermodal processing in music. The authors use the recently proposed theory of phenomenal space of tones (Scruton, 1997), but without acknowledging the source of the scholarship. The theory of phenomenal tonal space (phenomenal tonal gravity) was introduced to music psychology a few years ago (Korsakova-Kreyn, 2005), and is still controversial among the music psychologists (as we have found upon submitting our paper in melodic rotation to *Brain and Cognition* a few months before Foster & Zatorre and Zatorre at al submitted their paper). The evocation of the theory of phenomenal tonal space by Zatorre et al appears as a surprise because the choice of melodic stimuli in their

study does not offer any support to this theory. It is difficult to think of retrograde of the familiar melodies as coherent melodic images.

The theory of phenomenal tonal space implies that melodies are the melodic shapes (melodic "individuals" in Scruton's words) in the dynamic field of tonal relationships. From here we can extrapolate that the melodic shapes in the tonal force field acquire the attribute of "tonal surface" thanks to the listener's ability to sense the logic of melodic thought in the tonal relationships, while our mind continuously compares tonal status of the discrete tones thus connecting them within phenomenal tonal space originating in the gradient of tonal attraction (tonal hierarchy, Krumhansl & Kessler, 1982). The choice of the spatial terminology in this explanation intends to accentuate the quasi-spatial properties of tonal space and melodic shapes. Zatorre et al wrote about systematically related attributes in music perception, but this is just a reformulating of the familiar concept of tonal hierarchy which appears as an empty abstraction in relation to the comparison of a melodic shape and a 3-D object in mental rotation task. The formulation itself is painfully inadequate to the theory of phenomenal tonal space, which the authors present at the conclusion of their paper.

The conceptualization of tonal space as dynamic field of phenomenal gravity has its roots in the philosophical works by Pavel Florensky (1925). This link cannot be guessed from the experimental design of Zatorre et al study. Moreover, Zatorre et al idea of "new sounds" created by the composers of classical music precludes any hope that the theory of phenomenal tonal space (and melodic shapes) has anything in common with the theoretical essence of Zatorre et al paper. This is why there is a dissonant between the study's experimental design and the sudden introduction of the Scruton's theory of melodic shape. The authors' statement of supermodal processing presents the theoretical foundation for the concept of melodic shape by retelling (with amazing succinctness) the Scruton's theory of detachment of tones of a melodic "individual" from the source(s) of sound production. Why this theory appears in Zatorre et al paper without any introduction, and why Scruton's name is not mentioned is a mystery.

Overall, the authors' choice of melodic stimuli undermines their study's theoretical frame (as related to mental rotation and melodic objecthood). The excellent experimental part of Zatorre at al research appears as non-congruent with those theoretical sections of the paper that refer to mental practicing of the musicians and to the association between melodies and visuo-spatial processing. This is in contrast to those pages of the paper that deal with linguistic processing and numerical thinking, since processing retrograde most likely involves the focusing on pitch-set per se (on membership in a tonality) The retrograde task in Zatorre et al study creates detachment from a melodic shape of a familiar melody and reorients attention to the individual melodic elements (tones) within tonal system of reference (scale). This creates a perfect counterpart to linguistic and numerical strings of discrete yet homogeneous elements. Actually, retrograde could be a control task for non-spatial melodic thinking.

The study's theoretical conclusion, which uses the latest and highly sophisticated scholarship from the music philosophy, appears as dissonant in juxtaposition with the poor understanding of the basic musical practice that is related to polyphony. The contrast is amplified by the logical unpreparedness of the theoretical statement. The primary source of the theory of tonal space is a dense reading that demands a solid training in music theory, the familiarity with music philosophy, and formidable sight-reading skill, for example, to follow Scruton's logic. Despite its brilliance, Scruton's book—"The Aesthetics of Music"—has a slow start because of the many difficulties awaiting the reader.

Summary

The choice of melodic task in Zatorre at al study addresses a special case of melodic transformation. Retrograde is cognitively a difficult mental operation which is exceptionally rare in musical practice and which appears exclusively in polyphonic music. The difficulties in processing retrograde are known not just from musical practice. The research in melodic contour showed that the retrograde is a notoriously difficult melodic task (Dowing 1971, 1972). A more recent study that compared mental rotation and melodic transformation (including retrograde) produced rather uncertain results (Cupchik et al, 2001). These behavioral studies involved comparisons between melodies and visuo-spatial processing. The uncertainty of Cupchik et al's results—and the reliable results of the excellent and widely-known Dowling's research in melodic contour—should have made Zatorre at al more careful in their selection of melodic stimuli. Particularly considering their interpretation of the data as the evidence of a possible share of neurophysiological correlates of melodic processing (within tonal chronotope of music) and visuo-spatial processing (within the space of Cartesian coordinates and gravity).

Moreover, the theory of supermodal processing has a powerful rival. The neuroimaging studies demonstrate that parietal cortices have non-spatial functions that are related to maintaining cognitive control, regardless of whether the stimuli are auditory or visual (Coull & Frith, 1998; Cusack, 2005; Husain & Nachev, 2007). Bearing in mind Zatorre at al comparison of retrograde with the specific and rather "unnatural" linguistic task, the greater emphasis on the theory of attentional control (mentioned in passing by the authors, similar to our paper) would be more appropriate for their study.

Footnote:

Russian mathematician and theologian Pavel Florensky wrote his influential book "Space-ness and Time in the Representational Arts" in 1925, amidst the horrors and destruction caused by the WWI, Socialist Revolution, and civil war. Despite dangers facing an independent thinker in a totalitarian state, Florensky never compromised his principles. He died in a concentration camp during Great Terror of the 1930-s. Florensky's works had been prohibited for publication till 1993, yet his ideas survived.

Epilogue

Тля ест траву, ржа — железо, а лжа — душу.

A. P. Chekhov, «Моя жизнь. Рассказ провинциала”