Musical Forces and Event Semantics

M.A. THESIS REPORT
SUPERVISOR: PAUL DEKKER

Department of Philosophy
University of Amsterdam

Mick de Neeve

9305017/mick@live.nl

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Abstract Larson's musical forces of gravity, magnetism, resistance, and inertia, are intended to link musical harmony to physical metaphors of motion. Schlenker's musical semantics is based on similar associations with the physical world but unlike Larson's forces it is not set up to be computational. Because Larson's forces are about note movements to harmonic stability, the framework implies note sequence groupings at stable boundaries, given common cadential harmonic motion. These groupings with forces assignments can then form the musical events needed in Schlenker's approach, which can then be mapped to structure-preserving external (world) events. In this way, a pitch-based computational underpinning for Schlenker's musical semantics may be obtained.

1 Introduction

This study aims to connect Philippe Schlenker's musical semantics with work on musical forces by Steve Larson. Both are attempts to establish links between music and the physical world. In Schlenker's case various features of music are associated with events or situations in the world, while Larson considers the idea that the motion of pitches in music are metaphorically and cognitively related to physical motions. This suggests that, as far as pitch and harmony are concerned, the two approaches can be linked, in the sense that Larson's musical forces can be used to constrain Schlenker's semantics and make it more formal. The approaches are broadly explained below.

1.1 Schlenker

Schlenker's *Prolegomena to Music Semantics* explores the idea that music has a semantics, which to him consists in music having a meaning that relates it to something which is external to the music itself. This semantics, according to the author, is a rule-governed manner by which music licenses inferences about a music-external reality ([Sch19], section 1.1, page 36). The basic idea is that inferences are drawn about so-called virtual sources (after Bregman [Bre90]), which are imagined to be responsible for the music's sounds. For example, a low-pitched sound might be associated with a large entity ([Sch19], page 52), and if it is getting louder then it may be infered that the entity is getting closer (*ibid*, page 50) - as Schlenker puts it, music semantics starts as sound semantics (page 37).

Pitch as it is described above then, is a characteristic of sound in general, but pitch in music is experienced in a more complex way. In this study, pitch is really the only feature, with no regard for low versus high pitch in the above sense, i.e. what octave music is in is ignored. Incidentally, the same goes for rhythm; notes are always regularly spaced. But what is important about pitches is their role in what Schlenker calls tonal pitch space ([Sch19], page 37). This has, in Schlenker's words, non-standard properties,[1] and within it, pitches can form sequences called scales that can be major or minor, and within such scales various chords can be constructed by stacking notes a third (major or minor third) apart. Depending on which note of the scale the chord construction is started, chord modes or degrees numbered from I to VII may be built, and these degrees are stable or unstable to different extents. Schlenker maps this tonal stability of a musical event to the stability of a virtual source in an external (world) event.

Schlenker associates virtual sources with voices. In some cases, a voice might be identified with an instrument in an orchestra, but it is also possible for the orchestra to be playing a single voice. Conversely, a single instrument can be capable of playing several voices as Schlenker points out. An obvious example is the piano ([Sch19], page 37), but it is also possible for other instruments, even monophonic ones without the ability to sound multiple

[1] It is non-Euclidian in the sense that C and G, i.e. a fifth interval, sound better together so are in a sense closer, than C and $C\sharp$, which are adjacent or a minor second apart.

notes simultaneously, to play more than one voice (viz. [vT13]). This is relevant for this study, since one of the goals is to show how simple note sequences may be separated into multiple voices (although this is limited to two here). Schlenker on the other hand, assumes throughout [Sch19] that the relevant virtual sources have been identified by the listener (page 47).

Schlenker's musical events then, are objects $M = \langle M_1, \ldots, M_n \rangle$, with M a voice, and $M_1, \ldots, M_n$ musical features of that voice, such as harmonic functions (the above chord degrees) or loudness (see [Sch19], section 6.2, (23), page 66 for an example). The denotational relationship with the music-external reality is then as follows (*ibid*, (24), page 66):

Definition 1.1.1. *Let M be a voice, with $M = \langle M_1, \ldots, M_n \rangle$. A possible denotation for M is a pair $\langle O, \langle e_1, \ldots, e_n \rangle \rangle$ of a possible object and a series of n possible events, with the requirement that O be a participant in each of $e_1, \ldots, e_n$.*

The goal being to be able to state when a series of events, or situation, is true of a piece of music, Schlenker defines this as follows (*ibid*, (25), page 67):

Definition 1.1.2. *Let $M = \langle M_1, \ldots, M_n \rangle$ be a voice, and let $\langle O, \langle e_1, \ldots, e_n \rangle \rangle$ be a possible denotation for M. M is true of $\langle O, \langle e_1, \ldots, e_n \rangle \rangle$ if it obeys the following requirements.*

(a) Time: The temporal ordering of $\langle M_1, \ldots, M_n \rangle$ should be preserved, i.e. it should be the case that $e_1 < \ldots < e_n$, where $<$ is ordering in time.

(b) Loudness: If M_i is less loud than M_k, then either
  - *(i) O has less energy in e_i than in e_k; or*
  - *(ii) O is further from the perceiver in e_i than in e_k.*

(c) Harmonic stability: If M_i is less harmonically stable than M_k, then O is in a less stable position in e_i than it is in e_k.

The above definition will be adapted in section 4.1 to accomodate the use of Larson's forces (the topic of the next few paragraphs). The goal of the proposed definition (4.1.2) plus others is to increase the computability of Schlenker's theory of musical semantics, since his method ([Sch19], section 4.8, page 56) relies on a human evaluator to state and demonstrate the meaning of a piece of music.

1.2 Larson

In *Measuring Musical Forces* [LV05], Steve Larson and Leigh VanHandel investigate listener's judgements of motion tendencies in three-note patterns, and how these are associated with what Larson calls the basic musical forces of gravity, magnetism, and inertia. These are broadly speaking the tendencies of notes to descend, to be attracted to a stable pitch, and to continue in the same pattern. While the paper aims to demonstrate that these forces contribute to the perception of the strength of a pattern completion, its use here is limited to a description of the forces, plus the additional derived force called opposing attractor. This force does not appear in Larson's earlier work on musical forces such as [Lar93], and it is not elaborated on in [LV05], but can nonetheless be considered interesting since it can be viewed as 'resisting the magnetic pull'.

In *Musical Forces and Melodic Patterns* [Lar97a], Larson argues that musical forces are essentially a metaphor that aid a listener in musical cognition. He claims that *"experienced listeners hear tonal music as purposeful action in a dynamic field of musical forces"*, and asserts that this links musical meaning with conceptual metaphor (page 56) – one of the few places where the author explicitly references meaning (but see also section 2).

The same paper lists several seven-note patterns (*ibid*, page 62), seven of which Larson says are so-called Schenkerian tonic-prolongation patterns (page 63). For this study, Larson's forces are computed for segmentations of a selection of patterns that end on the tonic, mediant, or dominant, i.e. on those pitches Larson considers stable (page 59). One feature of this pattern set is that they are all stepwise, i.e. each next-note interval is at most a whole tone, but a further pattern set with leaps (i.e. intervals larger than a whole tone) are is also considered, taken from [Lar04], table 14 on page 494, which lists the results of an experiment in which participants are asked to complete a melody given a two- or three-note cue. In addition, a snippet from Johann Sebastian Bach's solo suites for cello [Bac50] is analysed.

The distinction between stepwise patterns and those with leaps is significant since according to Larson, the occurence of a leap from a note n to m within a note sequence leaves a trace of n in musical memory which is displaced by a further note n' stepwise with respect to n ([Lar04], page 467). This situation can be viewed as if m belongs to a different musical stream as opposed to n and n', in line with findings from auditory scene analysis that small pitch steps in a monophonic musical line tend to be grouped together into a separate musical voice (Pressnitzer et al. [PSS11], page 5, figure 5). Consequently for the present study, leapwise examples have been segmented vertically into a primary stepwise voice accompanied by a secondary voice. The primary voicings of these as well as examples that were stepwise from the outset have subsequently were segmented horizontally into groupings that end on stable notes. For the segmentations thus obtained, Larson's musical forces were computed, and ultimately viewed as events to guide the inferences needed for Schlenker's musical semantics.

Importantly, what is a stable note appears to be determinable by harmonic motion, a point which Larson does not give the attention it seems to deserve in [Lar97a]. For example, page 60 lists the pattern *5-4-3-2-1* (which in *A minor* would be *e-d-c-b-a*) as being composed of *5-4-3*, and *3-2-1*, because the mediant (*3*) and the tonic (*1*) are stable from the tonic triad *1-3-5* (or *a-c-e* in *A minor*). However, *5-4-3-2-1* can be readily interpreted as a *iv-v-i* cadence (i.e. with chords *D-*, *E*, and *A-* in *A minor*). Under that interpretation, *5-4* would take on the harmonic degrees *2-1*, while *3-2* would become *6-5*, and *2-1* would stay as it is. So since *1* (tonic) and *5* (dominant) are then reinterpreted as stable notes, the sequence, rather than being grouped as *(5-4-3)* and *(2-1)* can actually be segmented into *(5-4)*, and *(3-2-1)*, and the latter might be sub-segmented into *(3-2)* and *(2-1)*, such that musical forces may be assigned to these groups and subgroups.

In *A minor*, this allows, instead of *((e-d-c),(b-a))*, the partial grouping *((e-d),(c,b))*, where *(c-b)* is significant in that it lands via a semitone interval, or Larson's magnetic attraction. It is suspected that such attractions may in fact not only drive listener preference for grouping, but also harmonic perception – and possibly ultimately musical meaning – but in any case, considering harmonic motion significantly enhances the potential for assigning candidate meanings, as will be illustrated in section 3. A final note: in the example above, the notes were given as a 1-based numerical sequence, but in the sequel they are given 0-based (so *5-4-3-2-1* is rendered as *4-3-2-1-0*, and tonic, mediant, and dominant as *0*, *2*, and *4*).

2 Larson and Schlenker's conception of musical meaning

Larson views musical meaning as a suggested quality of music, such that it allows a listener to experience feelings, action, or motion ([Lar97b], page 101).

According to the author, such suggestions arise in the perception because of the interplay of tensions; the aforementioned musical forces. These forces are viewed as musical motion, which is heard as a mapping of physical gesture onto musical space. Meaning arises not only from the musical objects at the musical surface, so to speak, but also from the creative perception of an experienced listener, which allows the listener to hear a fragment of music x as y, where y an assigned meaning, for example an ascending gesture (*ibid*, page 102). There can be a complex interplay between musical elements for meanings to emerge, for instance a C below the motion $[E, F, E]$ is not part of the motion that gives in to the magnetism (the semitone pull from F down to E), but it does give context to it by providing the information that the melody has landed on the stable third of C major (see page 131).

But despite setting out such basic views about the nature of musical meaning, Larson does not delve into the matter in great depth. Instead his focus is on the role of the forces, rather than on meanings that may be assigned by a listener because of their interplay. Or put differently, Larson focuses on how magnetism in the pattern $[E, F, E]$ prolongs *C major* rather than the traversal through a physical space it suggests, or an emotion this might instill in a listener. In other words, even though Larson puts his work on musical forces in a context of a physical motion based conception of musical meaning, he does stops short of exploring the nature of his idea of meaning.

For Schlenker on the other hand, musical meaning and semantics is the core concept in [Sch19]. He considers this to be part of a wider research programme of 'super semantics', that he says might also be called formal semiotics. According to the author, for any representational form it might be said that to know the meaning is to know the truth conditions (see [Sch18], section 1.1, page 366), and consequently, he suggests formal semantics could be developed for representational systems including pictures, gestures, music, or dance.

Schlenker studies gestures as they appear in sign languages as iconic features of linguistic communication (in the sense of icons in Peircian semiotics ([Pei98], pages 460-461), and conjectures that on a suitably abstract notion of iconicity, music may, like gestures, be said to resemble the events which feature as denotations in his conception of musical semantics. As indicated above, Larson hypothesises that listeners may hear musical fragments as gestures, under the influence of musical forces ([Lar97b], page 102), while for Schlenker, music, like gestures, licenses inferences on the basis of resemblances. So gestures are an apparent link between the respective approaches of Larson and Schlenker.

The super semantics programme of the latter can be viewed as extending formal semantics of language, and within this, musical semantics is viewed as generalising gestural semantics, due to the apparent lack of music resembling what it purports to denote. In other words, resemblance, or cases where communicative signs 'imitate' denotations, is considered as the more basic mode of communication, and indexical communication where signs have a causal connection to their denotations. Schlenker considers his musical semantics, at least initially, closer to viewing musical signs as indices, but, like Greenberg (*The Semiotic Spectrum* [Gre11]), he does not consider the classic Peircian trichonomy (icons, indices, and symbols [Pei67]) as strict.[2]

As indicated in section 1.1, according to Schlenker a piece of music can be given a semantics of events in the world that have the same structure as the events which occur in the music, by drawing licensed inferences about its virtual, or imagined, sources. To avoid contradictions, he proposes the so-called model-theoretic direction, in which the inferences are considered together as a consistent set of events or situations of which the musical piece can be said to be true (section 6.1, page 64). Formal as this sounds, as indicated the account relies on a human evaluator, who, beside stating a piece's musical meaning, needs to demonstrate it is a valid denotation by creating a minimally altered version of the music - which together with the original Schlenker calls a minimal pair – such that the stated semantic effect disappears in the 'minimal other' version. Incidentally, the author also proposes that the inferences are demonstrated to hold in non-musical domains as well (point 3 on [Sch19], page 56), but this aspect will be ignored here.

To recap and expand on the example from section 1.1, suppose a series of low, increasingly louder tones are played, an inference can be drawn about some imagined source being a relatively large object getting closer. And if the piece were to conclude with a descending *C major* scale, the additional inference may be drawn that the object has settled into some stable state. A denotation of the form $\langle O, \langle e_1, \ldots, e_n \rangle \rangle$ can then be posited according definition 1.1.1 above, for instance $\langle car, \langle mindistance, departure, maxdistance, stop \rangle \rangle$, which is true according to definition 1.1.2. An alternative denotation such as $\langle car, \langle mindistance, departure, maxdistance, crash \rangle \rangle$ would not be true,

[2] In fact he states that with tonal inferences, his analysis moves further away from Peircian indices ([Sch19], page 37, footnote 6), but whether this means it is then closer to symbols is not made clear.

since the *crash* event could not be infered from the stable state of ending on *C major*. The example can altered by playing each note with identical loudness, upon which the impression of a source moving away disappears.

One significant difference between Schlenker and Larson is that in Schlenker's account, any feature of the music may be considered, as long as it can be rendered in terms of identifiable musical events and plausibly mapped to events in the world, and that it is also possible to alter such a feature for the posited semantic effect to vanish. Larson on the other hand, considers only the pitch dimension. However, he does so computationally at what is arguably the minimal level of notes (or rather intervals), while Schlenker's broad stroke approach makes and tests conjectures at meanings at the level of musical passages.

This raises questions about levels of analysis and methodology. Should musical meanings be determined automatically on the basis of low-level definitions, or can they be hypothesised by human evaluators? And in the former case, can lower-level meanings be combined to arrive at meanings at a larger level of analysis, i.e. is there a role for the principle of compositionality of meaning? Or can Larson's methods be somehow used within a Schlenkerian approach? Because what both accounts have in common is the idea of a mapping between the musical and the physical realm, which, incidentally, is central to Schlenker's notion of what a musical semantics should be: it should denote a reality external to the music itself ([Sch19], section 1.1, page 36), and hence be able to go beyond the idea of 'internal semantics' (*ibid*, section 2.4, page 42), e.g. semantics viewed as a journey through pitch space (see for instance [GW13]).

It should be mentioned that Schlenker does refer to Larson in [Sch19]; thrice, in the context of discussions of the meaning of music in general terms of movement (section 4.3, page 50), continuation of perceived patterns (inertia, section 4.5, page 54), and with respect to the idea of agency (magnetism, section 5.1, page 57). But as Schlenker points out on page 54, he does not consider Larson's forces as a way of connecting musical features to the physical world in terms of primitives, the reason being that knowledge of the world should be sufficient to trigger (e.g.) inferences about energy differences. However, here an attempt is nonetheless made to summarise musical information in terms of Larson's forces in order to license such inferences.

3 Musical forces and segmentations

In order to get a grip on the issues sketched above, Larson's musical forces were computed for some of the note sequences refered to in section 1.2. Sequences were segmented into groups ending on root, mediant, or dominant, following Larson's requirement that forces are to be assigned to so-called stable triad chord notes ([LV05], page 120).

The section below gives the relevant definitions used to specify note sequences in the context of scales and segment them. The term 'palette' below has been borrowed from Van den Berg ([vdB96], chapter 1, pages 34-40). What follows below may be considered the syntax of the ideas presented here; the semantics will follow in section 4.

3.1 Definitions

Definition 3.1.1. *A scale palette is a 7-element list of semitone distances counted from the first element, or palette root (0). Examples include Ionic Major* $= [0, 2, 4, 5, 7, 9, 11]$*, Harmonic Major* $= [0, 2, 4, 5, 7, 8, 11]$*, Harmonic Minor* $= [0, 2, 3, 5, 7, 8, 11]$*, and Melodic Minor* $= [0, 2, 3, 5, 7, 9, 11]$*.*

Definition 3.1.2. *A scale is a tuple* $\langle P, M\rangle$ *where* P *is a scale palette, and* M *is the scale mode or 0-based index where counting starts in* P*. The resulting scale is a 7-element list starting with 0 and with each next element* S_i *having the cumulative sum value* $\sum_{i=0}^{6}(S_i - S_{i-1})$ *mod* 12*. For example, Aeolic Minor* $= \langle \textit{Ionic Major}, 5\rangle = [0, 2, 3, 5, 7, 8, 10]$*. Scales being 7 notes, an (implied)* 8^{th} *is assumed to be the octave.*

Definition 3.1.3. *A note sequence is a numerical list of note positions. A note position is the location of a note in a 7-note scale (relative to a root) defined as 0, and may be either positive, i.e. higher than the root, or negative. For any position p, its degree is given by* p *mod* 7*. Degrees are traditionally called tonic, supertonic, mediant, subdominant, dominant, submediant, and subtonic, and are often specified as Roman numerals, but here they are represented as 0-based numbers, i.e.* $0, \ldots, 6$*. A note sequence may contain rests, indicated by logical negation (*$\neg$*), i.e.* $[0, 1, 4, 3, 2]$ *and* $[0, 1, \neg, \neg, 2]$ *are both note sequences.*

Definition 3.1.4. *A stepwise note sequence is a note sequence where for each adjacent note position pair* $[p_1, p_2] : abs(p_2 - p_1) = 0$ or 1*. A leapwise note sequence is a note sequence that is not stepwise.*

Definition 3.1.5. *A horizontal note segmentation is a list of note sub sequences (or note segments) that is an exhaustive partition of a given note sequence, such that each sub sequence degree ends on a tonic, mediant, or dominant (i.e. on note degree 0, 2, or 4, or, for a note n, on degree n mod 7). For instance, $[[0,1,2],[3,4],[5,6,7]]$ is a horizontal segmentation of $[0,1,2,3,4,5,6,7]$.*

Definition 3.1.6. *A vertical note segmentation $S = S_1 : S_2$ is a separation of a given leapwise note sequence into two streams (which are also note sequences), as in two musical staffs with rests (cf. right and left hand piano parts), with the requirement that the first stream is stepwise. The first stream is called the* primary vertical segmentation *or* primary stream*, the second the* auxiliary vertical segmentation *or* auxiliary stream.

Definition 3.1.7. *For a note segment S, a* musical forces assignment *S/F consists in assigning a list F, which may contain the following values: g in case S is gravitational, $+m$ if S is upward magnetic, $-m$ if it is downward magnetic, $+r$ in case S is upward resisting, $-r$ if it is downward resisting, $-i$ if S is downward inertic, $+i$ in case it is upward inertic, i if S is still inertic, and $\backslash i$ if it is alternating inertic. These forces are defined below.*

Definition 3.1.8. *A note segment is* gravitational *(g) if it has length ≥ 2 and for its last pair $[p_1, p_2]$ it holds that $p_2 - p_1 < 0$.*

Definition 3.1.0.1. *A note segment is* magnetic *if its length ≥ 2 and for its last pair $[p_1, p_2]$ it holds that $abs(p_2 - p_1) = 1$ (i.e. in standard musical usage it gets to its final note by a semitone distance). It is* downward magnetic *($-m$) if $p_2 - p_1 = -1$, and* upward magnetic *($+m$) in case $p_2 - p_1 = 1$.*

Definition 3.1.9. *A note segment is* resisting *if it is not magnetic in the sense that it does not give in to magnetism. It is* downward resisting *($-r$) if its length ≥ 2 and for its last pair $[p_1, p_2]$ it holds that if $p_1 > p_2$, $\exists p_3$ such that $p_1 < p_3$ and $[p_1, p_3]$ is upward magnetic. It is upward resisting ($+r$) if $p_1 < p_2$ and $\exists p_3$ with $p_1 > p_3$, and $[p_1, p_3]$ is downward magnetic.*

Definition 3.1.10. *A note segment is* inertic *if follows some continued pattern. If it has length > 2 it is* downward inertic *($-i$) if for its elements $[p_1, \ldots, p_n]$ it holds that $p_1 > \ldots > p_n$, and is* upward inertic *($+i$) in case $p_1 < \ldots < p_n$. It is* still inertic *(i) if its length > 1 and $p_1 = \ldots = p_n$. The segment is* alternating inertic *($\backslash i$) if it has length > 3 and for its adjacent pairs $Q = [q_1, \ldots, q_n]$ (where $q_1 = [p_1, p_2]$) the following is true. For each consecutive $[q_i, q_j] \in Q$, set $q_i = [p_a, p_b]$ and $q_j = [p_b, p_c]$. Then either $p_a < p_b > p_c$ or $p_a > p_b < p_c$.*

In the next two subsections the assignment of Larson's forces from definitions 3.1.7 to 3.1.10 is looked at for several examples, the first ones stepwise, i.e. with only one voice (definition 4.1.1), and subsequently also leapwise, separated into two voices according to definition 3.1.6. In section 4 denotations are also considered.

Forces are assigned given a scale palette plus mode tuple (see definitions 3.1.1 and 3.1.2), since these determine where magnetic (semitone) attractions occur (e.g. in *C major*, based on $\langle \mathit{Ionic\ Major}, 0\rangle$, there is one leading up to the root note C, but in *A minor*, based on $\langle \mathit{Ionic\ Major}, 5\rangle$, there is no such semitone leading up to the root A).[3] While the first example is rendered based on simple major and minor scales, in the subsequent examples it is illustrated how harmonic motion within these scales may determine segmentations, as indicated at the end of section 1.2, and hence may also determine forces assignments (and so ultimately semantics).

3.2 Stepwise instances

As a first example, consider $[0, 1, 2, 3, 2, 1, 0]$, taken from [Lar97a], example 5, page 62 (note it is given 1-based there but 0-based here). Following definition 3.1.5, it can be segmented in a number of ways, for instance into $[[0, 1, 2, 3, 2], [1, 0]]$, into $[[0, 1, 2], [3, 2, 1, 0]]$, or $[[0, 1, 2], [3, 2], [1, 0]]$. So the following musical forces may be assigned, respectively, depending on whether the underlying scale is *Ionic Major* or *Aeolic Minor*.

Example 3.2.1.

- $[0, 1, 2, 3, 2, 1, 0]$

  a *Ionic Major*:

  $\boldsymbol{a_1}$ $[[0, 1, 2, 3, 2, 1, 0]/[g]]$

  $\boldsymbol{a_2}$ $[[0, 1, 2, 3, 2]/[g, -m], [1, 0]/[g]]$

  $\boldsymbol{a_3}$ $[[0, 1, 2]/[+i], [3, 2, 1, 0]/[g, -i]]$

  $\boldsymbol{a_4}$ $[[0, 1, 2]/[+i], [3, 2]/[g, -m], [1, 0]/[g]]$

  b *Aeolic Minor*:

  $\boldsymbol{b_1}$ $[[0, 1, 2, 3, 2, 1, 0]/[g, -r]]$

  $\boldsymbol{b_2}$ $[[0, 1, 2, 3, 2]/[g], [1, 0]/[g, -r]]$

  $\boldsymbol{b_3}$ $[[0, 1, 2]/[+m, +i], [3, 2, 1, 0]/[g, -r, -i]]$

[3] Though there is such a so-called 'leading tone' in harmonic and melodic minor scales (see for instance example 3.2.2 below).

$\boldsymbol{b_4}$ $[[0, 1, 2]/[+m, +i], [3, 2]/[g], [1, 0]/[g, -r]]$

$\boldsymbol{a_1}$ https://deneeve.github.io/ac/ma/ex/321.a1.mp3
$\boldsymbol{a_4}$ https://deneeve.github.io/ac/ma/ex/321.a4.mp3
$\boldsymbol{b_1}$ https://deneeve.github.io/ac/ma/ex/321.b1.mp3
$\boldsymbol{b_4}$ https://deneeve.github.io/ac/ma/ex/321.b4.mp3

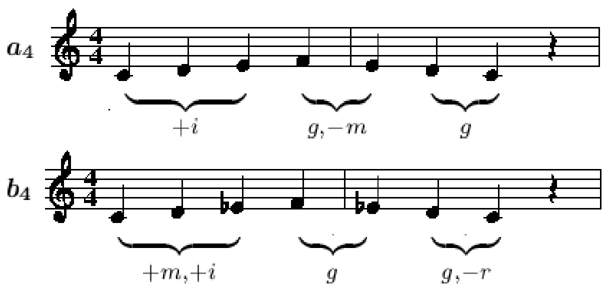

Figure 1: Example 3.2.1 in *C Ionic Major* (top) and *C Aeolic Minor* (bottom), with segmentations a_4 and b_4 and their musical forces assignments

NB: Links to sound files have been provided above, as is done for subsequent examples, for the note sequences as a whole as well as the segmentations. In the latter case, the start of a segment is indicated percussively by a rim shot ('side stick').

Figure 1 depicts (a_4) and (b_4) from example 1 in musical score format. Several observations can be made, for instance that at different segmentation levels, different musical forces can be seen to be active. E.g. for major as well as minor, breaking the 5-note pattern reveals upward inertic movement (upward and downward). But while the larger pattern is downward magnetic in the major case, the minor version reveals upward magnetism when segmented, with its descending segment resisting magnetism at the end – if it were to give in, the final notes would have been $[3, 2, 1, 2]$ instead, i.e. the sequence would have ended on the mediant.

Note that the current perspective is on possible interpretations of given musical snippets, but Larson's wider aim is to understand how musical forces shape (experienced) listener's expectations of possible musical completions ([Lar04], page 458-9). These completions are supposedly made on internalised basic musical structures like scales and triad chords which are embellished, or filled in, by a process Larson calls auralisation. To auralise means to internally hear, i.e. imagine, sounds that are not physically present (*ibid*, page 467). Embellishment is then a process of picking notes from the scale, or reference alphabet, to fill in a structure that moves towards notes from the goal alphabet (the triad chord notes because these are stable). See *ibid*, page 466, figure 1, for an example.

Following this idea for example 3.2.1 ((a_4) and (b_4)), a reference alphabet of the abstract scale notes could be used, i.e. $\mathrm{R} = [0, 1, 2, 3, 4, 5, 6, 7]$, and the triad $G = [0, 2, 4]$ as goal alphabet. The latter might then be split in two constituent thirds intervals of i.e. $G_1 = [0, 2]$, and $G_2 = [2, 4]$, with G_1 reversed into $G_1' = [2, 0]$. The segmentations (a_4) and (b_4) could then be viewed as (interwoven) embellishments, with the sequence $[0, 1, 2]$ derived from G_1, $[2, 3, 2]$ from G_2, and $[2, 1, 0]$ from G_1'. This way of looking at sequences and segmentations may be useful if the objective is to view them grammatically, i.e. as derivable from abstract structures.

The next example is also taken from example 5 in [Lar97a] (and is considered in harmonic minor mode; see definition 3.1.1). Its purpose is to demonstrate that simple note sequences can be heard as following a particular harmony, and when this is so, what is perceived as a stable tone alters, and hence so can the segmentation, and the musical forces that can be assigned. This is roughly in line with Larson's ideas on auralisation (sketched above) and contextual (in)stability – which means that a more stable note can be auralised to which a heard note then moves ([Lar97b], page 106), i.e. contextual stability means there is no such stabler auralisation. However, the notion of contextual stability suggested here is broader, and does not only involve the auralisation of expected notes, but also of implied concurrent notes.

Example 3.2.2.

- $[4, 3, 2, 1, 0, -1, 0]$

  $\boldsymbol{a}$ $[[4, 3, 2, 1, 0, -1, 0]/[+m]]$

  $\boldsymbol{b_1}$ $[[4, 3, 2, 1, 0]/[g, -r, -i], [-1, 0]/[+m]]$

  $\boldsymbol{b_2}$ $[[4, 3, 2]/[g, -i], [1, 0]/[g, -r], [-1, 0]/[+m]]$

  $\boldsymbol{c_1}$ $[[4, 3]/[g, -r], [2, 1]/[g, -m], [0, -1, 0]/[+m]]$

  $\boldsymbol{c_2}$ $[[4, 3]/[g, -r], [2, 1]/[g, -m], [0, -1]/[g, -m], [0]/[+m]]$

  $\boldsymbol{c_2'}$ $[[4, 0]/[g, -r], [4, 4]/[g, -m], [0, 2]/[g, -m], [0]/[+m]]$

$\boldsymbol{a}$ `https://deneeve.github.io/ac/ma/ex/322.a.mp3`
$\boldsymbol{b_2}$ `https://deneeve.github.io/ac/ma/ex/322.b2.mp3`
$\boldsymbol{c_2}$ `https://deneeve.github.io/ac/ma/ex/322.c2.mp3`
$\boldsymbol{c_2'}$ `https://deneeve.github.io/ac/ma/ex/322.cp2.mp3`

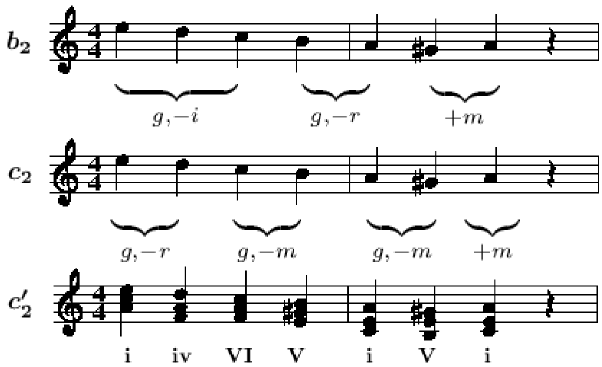

Figure 2: Example 3.2.2 in *A Harmonic Minor* with segmentations b_2 and c_2, with musical forces assignments, plus the harmonisation given by c_2'

Segmentation (b_2) represents the 'normal' case where musical forces are assigned on the basis of the segment having a stable end note, but in segmentation (c_1) this is not the case, at least not at first sight. In order to arrive at (c_1), some adjustments to the definitions in section 3.1 would be required, which will be postponed for now. But the general idea will be outlined here.

The segmentation in (c_1) represents a 'walking' grouping of the notes which seems natural, but violates the requirement in definition 3.1.5 that segments end on tonic, mediant, or dominant, i.e. the stable notes. Notably, the first segment ends on the subdominant, which is considered unstable to such a degree that it is also known as an 'avoid note'. As pointed out in Honshuke ([Hon97], page 14), in the construction of melody one should not start with the subdominant, nor hold it or end on it. As the author puts it (and noting that F is subdominant of C), *"as soon as the note F is played over C Maj chord, it destroys a sense of Major harmony"* – this being the same as D over *A minor* in minor modes.

However, it needs not be the case that a D would be heard as being played 'over' *A minor* in the example, since it would not be unnatural for this to actually be *D minor* instead. The underlying harmony would then be a so-called *I-IV-V-I* cadence – or more accurately, *i-iv-V-i* in a harmonic minor scale palette – which is a common progression employed to provide harmonic closure and satisfaction (viz. [Rie00], paragraph 9, page 101, and paragraph 14, page 102). This supports the segmentation (c_1). For the further segmentation of the last grouping in (c_2), one could assume an ending in a so-called authentic *V-I* cadence, and to avoid the dissonance of an augmented fifth interval in the first note of the second segment, an inserted *VI* would complete the harmonic motion to *i-iv-VI-V-i-V-i*. In *A minor* (harmonic) this would imply the progression *A-, D-, F, E, A-, E, A-* (see the bottom of figure 2, and for sound, see `https://deneeve.github.io/ac/ma/ex/322.cp2.mp3` – the link that also appears in example 3.2.2 under (c_2') – and which renders, or 'auralises', the example in this harmonised form).

Interpreted in this way, the last notes of the first three (c_2) segments are no longer the non-stable subdominant, supertonic, and subtonic – which they are only from the perspective of a static tonic. From the perspective of the implied chords, or temporary/dynamic tonics, they are tonic, dominant, and mediant, respectively, as shown in (c_2'). This suggests a relationship between grouping and harmonic perception, and plausibly ultimately with the meaning of segments as well.

Some further remarks regarding example 3.2.2. Firstly, in (c_2) the last segment is a single note that is assigned (upward) magnetism even though the minimum sequence length for force assignment is 2. This is in apprehension of allowing a singleton segment to be associated with the last note of its precursor (and/or with the first note of its successor). Secondly, the aptness of the pairwise 'walking' grouping appears to stem from the semitone interval encountered in the second segment – in *A minor*, that would be between the notes C and B. For the same note sequence in *C major*, the semitone would be encountered between F and E, and there could be more of an inclination to keep the first segment as three notes because of this, i.e. as $[G, F, E]$. Similarly segmenting into $[G, F]$ and then $[E, D]$ would 'break' the semitone interval, like not having the pairwise grouping in (a_3) would. Although Larson defines magnetism in general terms as attraction to the nearest stable pitch, he gives special prominence to the stronger case of semitone magnetism ([Lar97a], page 59), and it seems to be a feature that drives segmentation.

3.3 Leapwise instances

This section gives some examples of segmentations and assignments of musical forces for note sequences that contain leaps. These are first segmented vertically into two concurrent sequences ('streams') of which at least one is stepwise, after which the sequences are horizontally segmented.

The first example is adapted from [Ren87], page 52, based on a structural analysis of the *d♯* subject from Bach's *Well-Tempered Clavier* (*Book II: Prelude and Fugue in D♯ minor*, BWV 877, in [Bac96]). It is given here according to the harmonic minor scale (in *A Harmonic Minor*).

Example 3.3.1.

- $[0, 1, 3, 2, 0, -1, 0]$

  a $[[0, 1, 3, 2, 0, -1, 0]/[+m]]$

  b $[[0, 1, \neg, \neg, 0, -1, 0]/[+m]]$:

  $[[\neg, \neg, 3, 2, \neg, \neg, \neg]/[g]]$

  c $[[0, 1, \neg, \neg]/[-r], [0, -1, 0]/[+m]]$:

  $[[\neg, \neg, 3, 2, \neg, \neg, \neg]/[g]]$

  d $[[0, 1, \neg, \neg]/[-r], [0, -1]/[g, -m], [0]/[+m]]$:

  $[[\neg, \neg, 3, 2, \neg, \neg, \neg]/[g]]$

  d′ $[[0, 4, \neg, \neg]/[-r], [3, 2]/[g, -m], [0]/[+m]]$:

  $[[\neg, \neg, 3, 2, \neg, \neg, \neg]/[g]]$

a `https://deneeve.github.io/ac/ma/ex/331.a.mp3`
c `https://deneeve.github.io/ac/ma/ex/331.c.mp3`
d `https://deneeve.github.io/ac/ma/ex/331.d.mp3`
d′ `https://deneeve.github.io/ac/ma/ex/331.dp.mp3`

In example 3.3.1, the vertical segmentation (b) puts subdominant and mediant into the auxiliary stream, leaving tonic, supertonic, and subtonic in the primary one. In (c) both streams have been segmented horizontally, which is really relevant for the primary stream - the auxilliary one just has, like (a), what one might call the trivial or base segmentation

Segmentation (c) shows that initially, the sequence resists the magnetic downpull to $[-1]$, i.e. the subtonic, before giving in to the upward magnetism in the resolution to the tonic, while all that happens in the auxiliary voice is gravitational. But as in example 3.2.2, a 'harmonised' segmentation has been created in (d), which exhibits how before giving in to upward magnetism, the initially resisted downward pull to the subtonic happens first. This is achieved by interpreting the passage as the concatenation of two so-called perfect cadences, i.e. as *V*-*i*-*V*-*i* – after an initial exposition of the root *i* (i.e. as *i*-*V*-*i*-*V*-*i*, or complete: *i*-*V*-*i*-*i*-*i*-*V*-*i*). In A harmonic minor this would mean *A-, E, A-, E, A-*. The new note degrees are shown in (d'), and as indicated in the example it can be heard here: `https://deneeve.github.io/ac/ma/ex/331.dp.mp3`, with its score depicted at the bottom of figure 3.

However, what the vertical segmentation misses is the upward magnetism

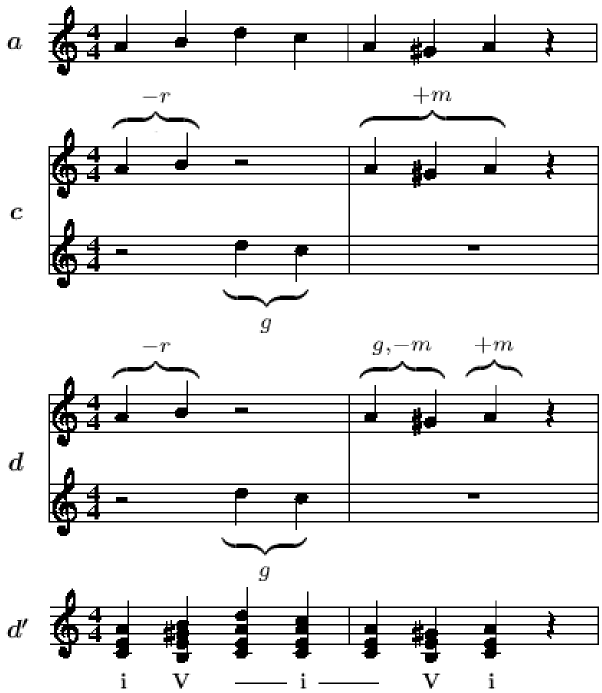

Figure 3: Example 3.3.1 in *A Harmonic Minor*; plain (a), with segmentations and musical forces assignments (c and d), plus harmonisation (d')

between the second and the fourth note in the 'base' sequence (a), i.e. $[0, 1, \neg, 2]/[+m]$. Larson would say that the leap $[1, 3]$ leaves the $[1]$ as a so-called trace in musical memory, which is displaced by the appearance of the $[2]$ ([Lar97b], pages 104-105), i.e. at that point the connection $[1, \neg, 2]$ is made. That they do indeed seem to be connected can be verified by listening to (a) (via the link in example 3.3.1), but because in the harmonisation (d_1) the second and fourth note are in different parts of the progression, their disconnection appears to be justified in this particular case.

The next example comes from [Lar04], page 494 (table 14, the third 'three-note cue' sequence, in major mode). Its purpose is to demonstrate that different vertical segmentations may arise and that these, as well as different harmonic interpretations, affect horizontal segmentation, and the assignment of forces.

Example 3.3.2.

- $[4, 2, 3, 1, 2, 1, 0]$

  a $[[4, 2, 3, 1, 2, 1, 0]/[g]]$

$\boldsymbol{b}$ $[[\neg, 2, 3, \neg, 2, 1, 0]/[g]]$:

$[[4, \neg, \neg, 1, \neg, \neg, \neg]/[g]]$

$\boldsymbol{b_1}$ $[[\neg, 2, 3, \neg, 2]/[g, -m], [1, 0]/[g]]$:

$[[4, \neg, \neg, 1, \neg, \neg, \neg]/[g]]$

$\boldsymbol{b_2}$ $[[\neg, 2, 3]/[+m], [\neg, 2, 1, 0]/[g]]$:

$[[4, \neg, \neg, 1, \neg, \neg, \neg]/[g]]$

$\boldsymbol{c}$ $[[4, \neg, 3, \neg, 2, 1, 0]/[g, -i]]$:

$[\neg, 2, \neg, 1, \neg, \neg, \neg]/[g, -r]$

$\boldsymbol{c_1}$ $[[4, \neg, 3, \neg, 2]/[g, -m, -i], [1, 0]/[g]]$:

$[[\neg, 2, \neg, 1, \neg, \neg, \neg]/[g, -r]]$

$\boldsymbol{c_2}$ $[[4, \neg, 3]/[g], [\neg, 2, 1, 0]/[g]]$:

$[[\neg, 2, \neg, 1, \neg, \neg, \neg]/[g, -r]]$

$\boldsymbol{c'_2}$ $[[4, \neg, 0]/[g], [\neg, 2, 1, 0]/[g]]$:

$[[\neg, 2, \neg, 4, \neg, \neg, \neg]/[g, -r]]$

$\boldsymbol{c_3}$ $[[4, \neg, 3]/[g], [\neg, 2, 1]/[g, -r], [0]/[g]]$:

$[[\neg, 2, \neg, 1, \neg, \neg, \neg]/[g, -r]]$

$\boldsymbol{c'_3}$ $[[4, \neg, 0]/[g], [\neg, 2, 4]/[g, -r], [0]/[g]]$:

$[[\neg, 2, \neg, 4, \neg, \neg, \neg]/[g, -r]]$

$\boldsymbol{a}$ https://deneeve.github.io/ac/ma/ex/332.a.mp3
$\boldsymbol{b_2}$ https://deneeve.github.io/ac/ma/ex/332.b2.mp3
$\boldsymbol{c_2}$ https://deneeve.github.io/ac/ma/ex/332.c2.mp3
$\boldsymbol{c'_2}$ https://deneeve.github.io/ac/ma/ex/332.cp2.mp3
$\boldsymbol{c_3}$ https://deneeve.github.io/ac/ma/ex/332.c3.mp3
$\boldsymbol{c'_3}$ https://deneeve.github.io/ac/ma/ex/332.cp3.mp3

Example 3.3.2 has vertical segmentations (b) and (c). Both have been segmented further, i.e. horizontally, but intuitively it is segmentation (c) that does justice to the alternating feel of the melody. However, the vertical segmentation (b), and in particular its horizontal subsegmentation (b_2), does capture the upward (magnetic) relation between the alternating subsequences of (c_2), viz. its first horizontal segment and its auxiliary stream.

Similarly, segmentation (c_1) shows a downward magnetic movement towards the mediant ([2]), but the aforementioned alternation makes it more coherent to have the mediant in another subsegment, as in (c_2). Moreover, in (c_1) the auxiliary vertical segmentation does not end on a stable pitch (it ends on the supertonic instead of on tonic, mediant, or dominant). But if the harmony is considered as a *I-IV-V-I* cadence (to be precise, as *[I, I, IV, V, I, I, I]*),

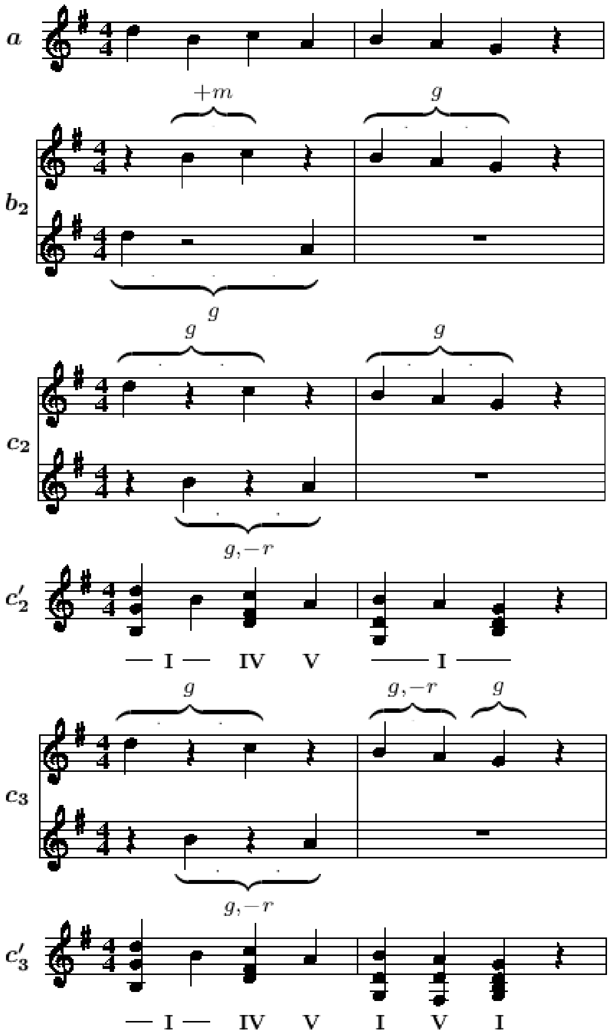

Figure 4: Example 3.3.2 in *G Ionic Major*; plain (a), with segmentations and musical forces assignments (b_2, c_2, and c_3), plus harmonisations (c_2' and c_3')

the segmentation (c_2) is possible. The local note degrees are shown in (c'_2) and (c'_3), respectively, with the group-end notes in these cases either tonic, mediant, or subdominant (sound files, as indicated in example 3.3.2, are at `https://deneeve.github.io/ac/ma/ex/332.cp2.mp3`, and `https://deneeve.github.io/ac/ma/ex/332.cp3.mp3`).

The final example of this section is an adapted (i.e. shortened) fragment from J.S. Bach's *Cello Suite III* [Bac50], to be precise from the *Bourrée* section's bars 5 and 6. It is almost twice as long as the previous examples, and is given in major mode (with the associated figure 5 and the sound files rendered in the original *C Ionic Major*). The purpose of the example is to illustrate implied polyphony in a (monophonic) note sequence, a goal Bach pursued in his writing for solo string instruments (viz. [Dav06]). The example can be seen to clearly separate into 'treble' and 'bass' lines, with the latter outlining harmonic motion, which can then drive horizontal segmentation and subsequent forces assignment (in section 4 this example is also used in a comparison with Schlenker's [Sch19] approach).

Example 3.3.3.

- $[1, 2, 3, 0, -1, 2, 3, -2, -3, 2, 3, -1, 0]$

  a $[[1, 2, 3, 0, -1, 2, 3, -2, -3, 2, 3, -1, 0]/[+m]]$

  b $[[\neg, 2, 3, \neg, \neg, 2, 3, \neg, \neg, 2, 3, \neg, \neg]/[\backslash i, +m]]$:

  $[[1, \neg, \neg, 0, -1, \neg, \neg, -2, -3, \neg, \neg, -1, 0]/[+m]]$

  c $[[\neg, 2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m]]$:

  $[[1, \neg, \neg, 0, -1]/[g, -m], [\neg, \neg, 2, -3]/[g], [\neg, \neg, -1, 0]/[+m]]$

  c′ $[[\neg, 1, 2, \neg, \neg]/[+m], [3, 4, \neg, \neg]/+m], [5, 4, \neg, \neg]/[+m]]$:

  $[[0, \neg, \neg, 6, 0]/[g, -m], [\neg, \neg, 6, 0]/[g], [\neg, \neg, 2, 0]/[+m]]$

a `https://deneeve.github.io/ac/ma/ex/333.a.mp3`
b `https://deneeve.github.io/ac/ma/ex/333.b.mp3`
c′ `https://deneeve.github.io/ac/ma/ex/333.cp.mp3`

In example 3.3.3, the Bach fragment has been segmented vertically in (b), and the primary as well as the auxiliary stream are shown horizontally segmented in (c). In (c'), note degrees have been given for the harmonic interpretation *II-VII-V-I*. This is on the assumption that the 'bass' voice of the auxiliary stream outlines the roots (i.e. the tonics).

As can be read off (c'), all segment endings are tonic, mediant, or dominant,

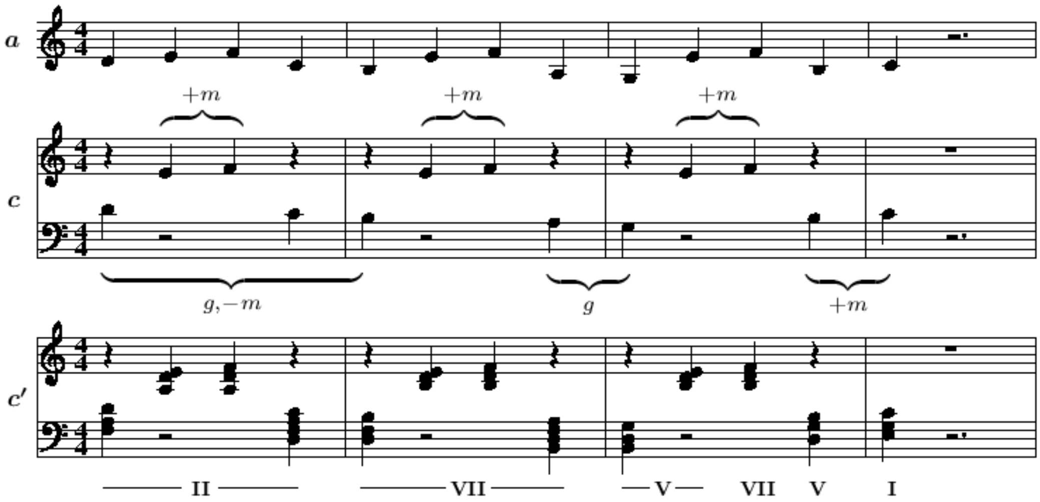

Figure 5: Example 3.3.3 in *C Ionic Major*; plain (a), with segmentations and musical forces assignments (c), and harmonisation (c')

but note particularly the third segment of the primary stream. That ending would have been on the subtonic if the *V* had been prolonged across the third measure, but by splitting the bar into *V-VII-V* this is avoided. However, in the context of the local dominant (*V*) harmony, it might actually be defendable to end on the subtonic as it is a characteristic element. Since the subtonic extends a *V* chord to a 7^{th} chord (also known as dominant 7^{th}) that is unique to its key (viz. [Kar16], page 9), one could argue it is a chord tone and hence functions as a group ending. Nevertheless the choice here is to stick to tonic, mediant, or dominant endings, despite the fact that one could question how stable a dominant is in a *VII* context, since it is a flattened fifth interval.[4]

The full harmony is then *[II, II, II, II, VII, VII, VII, VII, V, V, VII, V, I]*. Figure 5 depicts (a), (c), and (c') from the example in musical score format, and as indicated, the harmonisation associated with (c') is auralised in `https://deneeve.github.io/ac/ma/ex/333.cp.mp3`).

The forces assigned to the primary stream segments show the sequence continually giving in to upward magneticity, but as (c') reveals, this happens in various harmonic contexts. Meanwhile the auxiliary stream descends towards these contexts until it settles into the main key's tonic. In the next

[4] This B is arguably unstable in that it seems eager to resolve to E; the third of the next bar's I chord.

section, these observations form the basis for a comparison with Schlenker's [Sch19] approach to musical semantics.

4 Musical semantics and events

Schlenker's musical semantics focuses on the idea of events in the world as extra-musical denotations of musical pieces, with extra-musicality considered a necessary feature of a genuine semantics for the author ([Sch19], section 3.2, page 44). As indicated in section 2 here, Schlenker's central idea consists in mapping musical events onto events in the world such that structure is preserved. This is a causal relation between signs, or musical objects, and a fictional source (a voice, see definition 1.1.1) which is considered to be responsible for the musical sounds. The semantics then consists in inferences that can be drawn concerning events in which the source or sources participate. Schlenker thus proposes an event semantics, and it is suspected here that this is in fact close to a Neo-Davidsonian semantics (viz. [Cha14], page 3). Such a semantics can express statements about actions, agents that initiate them, as well as themes, or entities which undergo the events (*ibid*, page 5).

For instance, Schlenker gives an example denotation for Richard Strauss' *Also Sprach Zarathustra* ([Str79], [Sch19], pages 44 and 68) in terms of a sunrise which is actually a star appearing from behind a planet in space, where the sunrise can be taken as the event, the planet as the agent, and the star as the theme. This example is used in a comparison with Larson in section 4.3. But first Schlenker's voice and truth definitions will be adapted to fit in with Larson's methods as they are used here, and then the Bach example (3.3.3 above) will be reconsidered.

4.1 Definitions

This section aims to bring Schlenker's definitions as introduced in section 1.1 in line with Larson's ideas as specified in the definitions of section 3.1. Two concepts are clarified in this respect; that of a voice, and of the truth of a denotation with respect to a piece of music. These are needed to bring Larson in accordance with Schlenker and vice versa, in the subsequent sections 4.2 and 4.3.

Definition 4.1.1. *A voice is either a stepwise note sequence, or the primary or auxiliary stream of a leapwise note sequence. A* sub voice *is a horizontal segment of a voice.*

Definition 4.1.2. *Let $M = \langle M_1, \dots, M_n \rangle$ be a voice or a sub voice, and $\langle O, \langle e_1, \dots, e_n \rangle \rangle$ a possible denotation for M (in the sense of definition 1.1.1). M is true of $\langle O, \langle e_1, \dots, e_n \rangle \rangle$ if it obeys the following requirements.*

(a) *Time: The temporal ordering of $\langle M_1, \dots, M_n \rangle$ should be preserved, i.e. it should be the case that $e_1 < \dots < e_n$, where $<$ is ordering in time.*

(b) *Forces: If M is assigned the following forces then these act to move O to a position of – relative – stability.*

   (i) *If M is gravitational, then O moves, under the influence of gravity or a similar constant force, to a stable position closer to an observer or one of less energy, i.e. if $[M_1, \dots, M_n]/F$ with $g \in F$, then e_n is closer to the observer or has less energy than e_1 (this and subsequent clauses assume Schlenker's ideas on pitch inferences [Sch19], section 4.4, pages 52-53, where higher pitch or frequency is associated with more events or energy, and/or lower pitch with a larger entity, which is here also taken to be interpretable as being closer).*

   (ii) *If M is magnetic then O is attracted to a stable position; in case M is downward magnetic (if $[M_1, \dots, M_n]/F$ with $-m \in F$) then O will be in a position of less energy or has moved closer to an observer (e_n is closer to the observer or has less energy than e_1), and if M is upward magnetic (if $[M_1, \dots, M_n]/F$ with $+m \in F$), it will be in a position with more energy or further away from the observer (e_n is further from the observer or has more energy than e_1).*

   (iii) *If M is resisting then O does work to reach a stable position, that is less energetic or closer to an observer in case M is downward resisting – i.e. if $[M_1, \dots, M_n]/F$ with $-r \in F$ then e_n has less energy or is closer to the observer than e_1 – and more energetic or further from the observer if M is upward resisting – i.e. in case $[M_1, \dots, M_n]/F$ with $+r \in F$ then e_n has more energy or is further the observer than e_1.*

   (iv) *If M is inertic then O follows a pattern to a stable position – which may be voluntary through action or involuntary via the effect of a force (with the latter case comparable to gravity). If M is downward inertic then O moves steadily to a less energetic position or closer to an observer (if $[M_1, \dots, M_n]/F$ with $-i \in F$ then e_n has less energy or is closer to the observer than e_1), and if M is upward inertic, O follows a steady pattern to a position with higher energy or further from the observer (if $[M_1, \dots, M_n]/F$*

with $+i \in F$ then e_n has less energy or is closer to the observer than e_1). If M is still inertic then O remains in the same position (if $[M_1, \ldots, M_n]/F$ with $i \in F$ then e_n has the same energy or is in the same position as e_1)). Finally, if M is alternating inertic then O follows a regular but alternating pattern ($[M_1, \ldots, M_n]/F$ with $\backslash i \in F$), which is to a less energetic position or closer to the observer if M is also gravitational ($g \in F$), or to a position with more energy or further from the observer if M is not gravitational and has even length; else O ends up in the same position (as specified above).

(c) *Harmonic stability: If M_i is less harmonically stable than M_k, then O is in a less stable position in e_i than it is in e_k.*

A note that needs be made with respect to the above is that not all concepts have been unpacked, e.g. 'to do work' in clause (*iii*) – which is intended to be in opposition to the magnetism (in the sense of 'no work needed') of the preceding clause. Relatedly, 'to follow a pattern' in clause (*iv*) has only be specified for a limited number of cases.

4.2 Larson according to Schlenker

In this section, two examples that were previously analysed according to Larson's musical forces are reconsidered in order to see what can be made of them by applying Schlenker's method to them. The first example here (example 3.2.2 above) is stepwise, and taken from [Lar97a]. Relevant parts of the example are recalled below, and a 'minimal other' (m_o) has been added to create the minimal pair $\langle (c_2), (m_o) \rangle$ (see section 2 here, as well as [Sch19], section 4.8, page 56).

Example 4.2.1.

- $[4, 3, 2, 1, 0, -1, 0]$

$$\boldsymbol{c_2} \quad [[4,3]/[g,-r],[2,1]/[g,-m],[0,-1]/[g,-m],[0]/[+m]]$$
$$\boldsymbol{c'_2} \quad [[4,0]/[g,-r],[4,4]/[g,-m],[0,2]/[g,-m],[0]/[+m]]$$
$$\boldsymbol{m_o} \quad [[4,3]/[g,-r],[2,1]/[g,-m],[0,-1]/[g,-m],[-2]/[g,-i]]$$
$$\boldsymbol{m'_o} \quad [[4,3]/[g,-r],[2,1]/[g,-m],[0,-1]/[g,-m],[0]/[g,-i]]$$

$\boldsymbol{c_2}$ https://deneeve.github.io/ac/ma/ex/421.c2.mp3
$\boldsymbol{c'_2}$ https://deneeve.github.io/ac/ma/ex/421.cp2.mp3
$\boldsymbol{m_o}$ https://deneeve.github.io/ac/ma/ex/421.mo.mp3
$\boldsymbol{m'_o}$ https://deneeve.github.io/ac/ma/ex/421.mpo.mp3

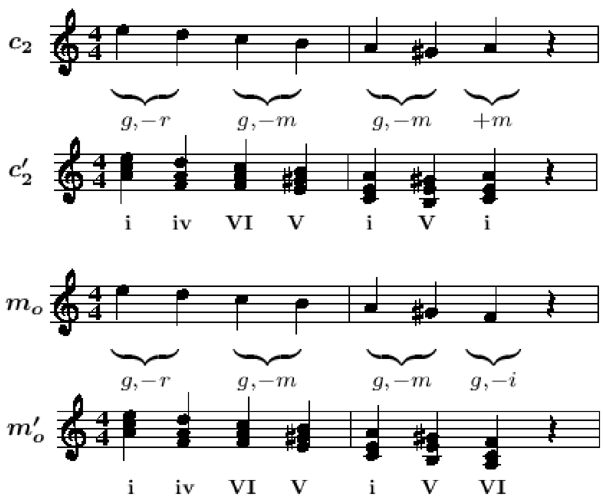

Figure 6: Example 4.2.1 in *A Harmonic Minor* with segmentations c_2 and m_o and their musical forces assignments, plus harmonisations c'_2 and m'_o

The minimal other in example 4.2.1 continues the note sequence's downward motion, and prevents it from resolving to the tonic (it moves to the VI^{th} mode instead). The example is depicted in musical score format in figure 6.

Recall that in section 3.2, it was the harmonic sequence *[i, iv, VI, V, i, V, i]* that permitted the segmentation ($c2$) for this note sequence. Following Schlenker's method as described in ([Sch19], section 6.2, page 65), the note sequence in example 4.2.1 is represented as a sequence of quadruples $\langle harmony, gravity, magnetism, resistance\rangle$.

Moreover, it is assumed that the stability ordering of harmonic functions is as indicated in (*ibid*, section 5.3, page 59), i.e. $IV < V < VI < I$ (ignoring any possible difference in major vs. minor scale degree stability). Then a sequence of four musical events may be discerned (as many as there segments in (c_2)), with the following sequence of where the harmony transistions to: *[IV, V, V, I]*. The musical events in example 4.2.1 can then be rendered as in equation 4.2.2.

Equation 4.2.2.
$M = \langle\langle iv, g, 0, -r\rangle, \langle V, g, -m, 0\rangle, \langle V, g, -m, 0\rangle, \langle i, 0, +m, 0\rangle\rangle$

Then using definition 4.1.2, a possible denotation can be created – i.e. a structure-preserving mapping from the musical events to (fictional) world events. This will be like (e.g.) the *sun-rise* event as in ([Sch19], (26), page 68), except that the sub events are given as attribute/value pairs.

The proposed denotation is *kite-landing* in equation 4.2.3 below. There are four musical events in equation 4.2.2 to be mapped to 'world' events of which the middle two are the same (so essentially there are three). As for the first one, $\langle iv, g, 0, -r\rangle$, note that $-r$ refers to work done by the kite flyer (which perhaps ought to strictly be a separate object) according to definition 4.1.2 ($b.iii$) to manipulate windfall to go over the kite. Once that happens the kite gives into the gust, i.e. it gives into magnetism, which is the musical event $\langle V, g, -m, 0\rangle$ twice in a row, and as it decends it comes closer to the observer by $-m$ in clause ($b.ii$). All the while, stability is getting greater as the harmony moves from *iv* via V to *i*, which is interpreted as that being higher above ground is less stable than to be closer to it. This leads to the events in equation 4.2.3

Equation 4.2.3.

$$\begin{aligned} \textit{kite-landing} = \quad \langle \textit{kite}, \quad & \langle\langle \textit{wind} = \textit{below}, \textit{height} = \textit{max}\rangle, \\ & \langle \textit{wind} = \textit{above}, \textit{height} = \textit{med}\rangle, \\ & \langle \textit{wind} = \textit{above}, \textit{height} = \textit{min}\rangle, \\ & \langle \textit{wind} = \textit{none}, \textit{height} = \textit{ground}\rangle\rangle\rangle \end{aligned}$$

So the sequence of events in equation 4.2.3 is that of a kite that moves from an unstable position in the air to the ground under the influence of gravity and the orientation of the wind relative to it. The descending pitches have been summarised in M (equation 4.2.2) by the continual presence of the gravitational musical force. The $-r$ in M's first event indicates that the first note, 4, has a stable pitch a semitone above it in the context of the *i-iv* harmony (the tonic). The $+m$ of the last segment actually signifies the final gravitational attraction to the ground, i.e. pitch height does not have to denote physical height (cf. Schlenker's remark that musical sound may denote events where no sound is produced, [Sch19], section 1.2, page 38).

In Schlenker's account then, the event of equation 4.2.3 is true of the sequence in example 4.2.1 (c_2). It is not true of (m_o), since that sequence continues to move to the VI^{th} mode and does not conclude on 'stable ground'.

The second example is the one taken from Bach's *Cello Suite III*'s *Bourée I* section, used earlier as example 3.3.3. Relevant parts of it are recalled below, with again a minimal other (m_o), but additionally an different (primary) segmentation (d). The example is depicted in figure 7.

Example 4.2.4.

- $[1, 2, 3, 0, -1, 2, 3, -2, -3, 2, 3, -1, 0]$

  $\boldsymbol{c}$ $[[\neg, 2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m]]:$
  $[[1, \neg, \neg, 0, -1]/[g, -m], [\neg, \neg, 2, -3]/[g], [\neg, \neg, -1, 0]/[+m]]$

  $\boldsymbol{c'}$ $[[\neg, 1, 2, \neg, \neg]/[+m], [3, 4, \neg, \neg]/ + m], [5, 4, \neg, \neg]/[+m]]:$
  $[[0, \neg, \neg, 6, 0]/[g, -m], [\neg, \neg, 6, 0]/[g], [\neg, \neg, 2, 0]/[+m]]$

  $\boldsymbol{m_o}$ $[[\neg, 2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m]]:$
  $[[1, \neg, \neg, 1, 1]/[i], [\neg, \neg, 1, 1]/[i], [\neg, \neg, -1, 0]/[+m]]$

  $\boldsymbol{m'_o}$ $[[\neg, 2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m], [2, 3, \neg, \neg]/[+m]]:$
  $[[1, \neg, \neg, 1, 1]/[i], [\neg, \neg, 1, 1]/[i], [\neg, \neg, -1, 0]/[+m]]$

  $\boldsymbol{d}$ $[[\neg, 2]/[], [3, \neg, \neg]/[+m], [2]/[-m], [3, \neg, \neg]/[+m], [2]/[-m], [3, \neg, \neg]/[+m]]:$
  $[[1, \neg, \neg, 0, -1]/[g, -m], [\neg, \neg, -2, -3]/[g], [\neg, \neg, -1, 0]/[+m]]$

  $\boldsymbol{d'}$ $[[\neg, 2]/[], [2, \neg, \neg]/[+m], [2]/[-m], [2, \neg, \neg]/[+m], [2]/[-m], [2, \neg, \neg]/[+m]]:$
  $[[0, \neg, \neg, 0, 0]/[g, -m], [\neg, \neg, 0, 0]/[g], [\neg, \neg, 2, 0]/[+m]]$

$\boldsymbol{c}$ `https://deneeve.github.io/ac/ma/ex/424.c.mp3`
$\boldsymbol{c'}$ `https://deneeve.github.io/ac/ma/ex/424.cp.mp3`
$\boldsymbol{m_o}$ `https://deneeve.github.io/ac/ma/ex/424.mo.mp3`
$\boldsymbol{m'_o}$ `https://deneeve.github.io/ac/ma/ex/424.mpo.mp3`
$\boldsymbol{d}$ `https://deneeve.github.io/ac/ma/ex/424.d.mp3`
$\boldsymbol{d'}$ `https://deneeve.github.io/ac/ma/ex/424.dp.mp3`

Figure 7: Example 4.2.4 in *C Ionic Major*, with segmentations and musical forces assignments (c and d), minimal pair $\langle c, m_o \rangle$, and harmonisations (c'' and d')

Segmentation (c), as pointed out for example 3.3.3, relies on a *II-VII-V-I* progression (*[II, II, II, II, VII, VII, VII, VII, V, V, VII, V, I]* to be precise). The minimal other (for the minimal pair $\langle c, m_o \rangle$) has a drawn-out *II*, to end on the *V-I* as (c) does, but its character difference compared to (c) is obstinacy, in that the auxiliary voice stays on the same note until the concluding resolution.

Following Schlenker's reasoning on the relative stability of harmonic functions ([Sch19], section 5.3, page 59), it can be argued that *VII* < *V* because it shares two out of three notes; for the same reason that *II* < *IV*. So on that account, for the harmonic functions in the present example the ordering *VII* < *II* < *V* < *I* is assumed to hold.

Example 4.2.4 has two voices or virtual sources, primary and auxiliary, which will be called M_p and M_a, respectively, and each of which has three segments. Given the assignments of musical forces in (c), these give rise to the following musical events (following the template from example 4.2.1 but omitting resistance):

Equation 4.2.5.
$M_p = \langle \langle \mathit{II}, 0, +m \rangle, \langle \mathit{VII}, 0, +m \rangle, \langle \mathit{VII}, 0, +m \rangle \rangle$
$M_a = \langle \langle \mathit{VII}, g, -m \rangle, \langle V, g, 0 \rangle, \langle I, 0, +m \rangle \rangle$

Assuming concurrency of the voices, a *sea-sun-set* world event can be said to be true of example 4.2.4 (c), with the M_p voice aligned with *'sea'* and M_a with *'sun'* in equation 4.2.6. It is not true of the example's minimal other (m_o), since that has an abrupt rather than a gradual movement to stability.

Equation 4.2.6.

$$\begin{array}{lll} \textit{sea-sun-set} = & \langle\langle sea, & \langle waves = incoming, surf = medium \rangle, \\ & & \langle waves = incoming, surf = high \rangle, \\ & & \langle waves = incoming, surf = high \rangle\rangle, \\ & \langle sun, & \langle\langle view = full, motion = down \rangle, \\ & & \langle view = half, motion = down \rangle, \\ & & \langle view = none, motion = none \rangle\rangle\rangle \end{array}$$

As noted, the example has an alternative segmentation in (d), in an attempt to capture the alternating nature of the primary voice, since Schlenker does tend to focus on such detailed features of the music he considers (e.g. [Sch19], example (46), page 89).

In segmentation (d), the harmony has been reinterpreted to *[VII, I, II, I,* *VII, I, II, VI, V, I, II, V, I]* in order to segment the notes as singletons. This in order to adhere to Larson's requirement that forces are movements to stable notes (the local degrees are shown in (d') in example 4.2.4), but also to illustrate that there are various possible harmonisations for a particular melody. Equation 4.2.7 lists the musical events for segmentation (d).

Equation 4.2.7.
$M_p = \langle\langle I, 0, 0\rangle, \langle II, 0, +m\rangle, \langle I, 0, -m\rangle, \langle II, 0, +m\rangle, \langle I, 0, -m\rangle, \langle II, 0, +m\rangle\rangle$
$M_a = \langle\langle VII, g, -m\rangle, \langle V, g, 0\rangle, \langle I, 0, +m\rangle\rangle$

Based on the above, a different event in the world might now be true of the example (4.2.4 (d)), i.e. *bird-landing* given below. Like *sea-sun-set*, the auxiliary voice, which is the same in both segmentations, represents motion towards stability, but now the primary voice can represent wing motion due to the alternating (magnetic) motion between its two notes (incidentally, the first wing position has been left blank because no musical force can – presently – be assigned to an initial singleton note).

Formally according to definition 4.1.2, the mapping is that initially the wing position is unclear, since there is no magnetism at this point. But subsequently it alternates, and coherently the idea should be that the energy position of the wings alternate, again by clause ($b.ii$) of the definition, with $+m$ being towards greater energy. Then the following denotation may be said to hold:

Equation 4.2.8.
$$\begin{aligned} \textit{bird-landing} = \quad & \langle\langle \textit{wings}, \langle \textit{position} = \textit{unknown}\rangle, \langle \textit{position} = \textit{down}\rangle, \\ & \qquad \langle \textit{position} = \textit{up}\rangle, \\ & \qquad \langle \textit{position} = \textit{down}\rangle, \langle \textit{position} = \textit{up}\rangle, \\ & \qquad \langle \textit{position} = \textit{down}\rangle\rangle, \\ & \langle \textit{body}, \langle\langle \textit{motion} = \textit{down}\rangle, \langle \textit{motion} = \textit{down}\rangle, \\ & \qquad \langle \textit{motion} = \textit{none}\rangle\rangle\rangle \end{aligned}$$

The above equation also expresses body movement in the sense that motion continues to gravitationally descend, with the final M_a clause of equation 4.2.8 assigned $+m$, consistent with the idea that the kite lands (further) from the observer, again in line with ($b.ii$) of definition 4.1.2.

In the next section, two final examples are considered, taken from Schlenker [Sch19], in order to see how a Larsonian musical forces analysis on them fares.

4.3 Schlenker according to Larson

There are not many examples in [Sch19] for which the author gives a full semantics as well as that the music's character is determined by pitch, as it is here. The first example in this section, however, focuses on cadences like a number of examples of the ones above did. It is adapted from Wolfgang Amadeus Mozart's *Ah vous dirai-je Maman* ([Moz78]; [Sch19], section 5.3, example (19), page 60). Effectively it is a 'variation on a variation', i.e. the adaption constitutes rewriting the bass notes into the melody in order to end up with a monophonic line (rendered in *C Ionic Major*).

Example 4.3.1.

- $[0, 0, 4, 2, 5, 3, 4, 2, 3, 1, 2, 0, 1, 0, -1, 0]$

  $\boldsymbol{a}$ $[[\neg, \neg, 4, \neg, 5, \neg, 4, \neg, 3, \neg, 2, \neg, 1, 0, -1, 0]/[+m]]$:
  $[[0, 0, \neg, 2, \neg, 3, \neg, 2, \neg, 1, \neg, 0, \neg, \neg, \neg, \neg]/[]]$

  $\boldsymbol{b}$ $[[\neg, \neg, 4, \neg]/[], [5, \neg, 4, \neg]/[g], [3, \neg, 2, \neg]/[g, -m], [1, 0, -1]/[g, -m, -i], [0]/[+m]]$:
  $[[0, 0, \neg, 2]/[], [\neg, 3, \neg, 2]/[g, -m], [\neg, 1, \neg, 0]/[g, -m], [\neg, \neg, \neg]/[], [\neg]/[]]$

  $\boldsymbol{b'}$ $[[\neg, \neg, 4, \neg]/[], [2, \neg, 4, \neg]/[g], [6, \neg, 2, \neg]/[g, -m], [0, 4, 2]/[g, -m, -i], [0]/[+m]]$:
  $[[0, 0, \neg, 2]/[], [\neg, 0, \neg, 2]/[g, -m], [\neg, 0, \neg, 0]/[g, -m], [\neg, \neg, \neg]/[], [\neg]/[]$

  $\boldsymbol{m_o}$ $[[\neg, \neg, 4, \neg]/[], [5, \neg, 4, \neg]/[g], [3, \neg, 2, \neg]/[g, -m], [1, 0, -1]/[g, -m, -i], [-2]/[g, -i]]$:
  $[[0, 0, \neg, 2]/[], [\neg, 3, \neg, 2]/[g, -m], [\neg, 1, \neg, 0]/[g, -m], [\neg, \neg, \neg]/[], [\neg]/[]]$

  $\boldsymbol{m'_o}$ $[[\neg, \neg, 4, \neg]/[], [2, \neg, 4, \neg]/[g], [6, \neg, 2, \neg]/[g, -m], [0, 4, 2]/[g, -m, -i], [0]/[+m]]$:
  $[[0, 0, \neg, 2]/[], [\neg, 0, \neg, 2]/[g, -m], [\neg, 0, \neg, 0]/[g, -m], [\neg, \neg, \neg]/[], [\neg]/[]$

$\boldsymbol{b}$ `https://deneeve.github.io/ac/ma/ex/431.b.mp3`
$\boldsymbol{b'}$ `https://deneeve.github.io/ac/ma/ex/431.bp.mp3`
$\boldsymbol{m_o}$ `https://deneeve.github.io/ac/ma/ex/431.mo.mp3`
$\boldsymbol{m'_o}$ `https://deneeve.github.io/ac/ma/ex/431.mpo.mp3`

Segmentation (b) depends on a *I-IV-V-I* harmony, or more precisely on *[I, I, I, I, IV, IV, I, I, IV, II, I, I, II, IV, V, I]*, as depicted in figure 8, and harmonised in (b') and the associated mp3 link (listed above). The point for Schlenker is the final *V-I* cadence, which in the 'minimal other' he changes to a so-called deceptive *V-VI*, which is less stable (viz. [Sch19], page 59), making the piece sound less conclusive. In example 4.3.1 the same effect is achieved by not having the final note give in to magnetism, but by letting it continue to descend, i.e. give in to gravity instead. It might be argued then that the conclusiveness of the piece is in part due to a seeming (intentional)

Figure 8: Example 4.3.1 in *C Ionic Major*, with segmentations and musical forces assignments (b and m_o), and harmonisations (b' and m'_o)

violation of physics laws, a point Schlenker makes with respect to musical semantics in general (*ibid*, section 3.1, page 43), although not in reference to this particular piece.

The final example of this section is one of the central ones in Schlenker; a snippet of Richard Strauss' *Also Sprach Zarathustra* [Str79], which the author links with imagery from the 1968 film *2001: A Space Odyssey* [Kub68]. Figure 9 shows the score and imagery as it appears in [Sch19] (section 3.2, page 44).

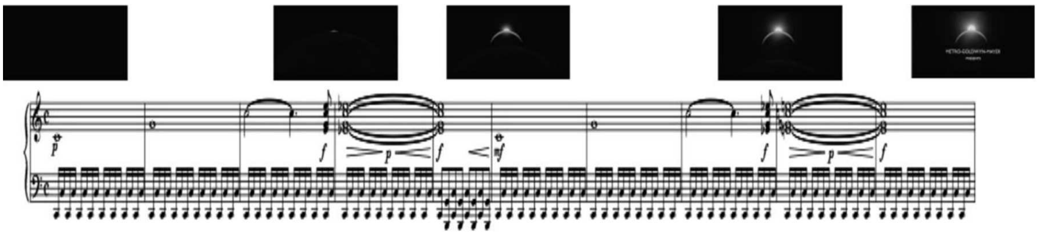

Figure 9: Opening bars from Strauss' *Also Sprach Zarathustra* annotated with imagery from Kubrick's *2001: A Space Odyssey* (example 6 in [Sch19]), video: `http://bit.ly/2DfiE3m`

Schlenker points out that the motion picture's imagery synchronises with a two-stage appearance of a star (sun) from behind a planet, with the first five measures corresponding to the first stage, and the last six to the second. According to the author, like the film, the music's antecedent-consequent structure *"certainly evokes the development of a phenomenon in stages as well"* (*ibid*, page 44). But importantly he uses features of loudness beside tonal ones, while it is only the tones that are available here.

In example 4.3.2, depicted in figure 10, an adaption of *Also Sprach Zarathustra* is rendered in 'Larsonian' form, and as it turns out, to make the example work, assumptions need to be made as to underlying key and scale, which may not be wholly realistic. Moreover, the semantics must be expanded in order to capture the effects in a way that is close to Schlenker's anayisis.

Example 4.3.2.

- $[0, 4, 7, 10, 9, \neg, 0, 4, 7, 9, 10]$

  a $[[0, 4, 7, 10, 9, \neg, 0, 4, 7, 9, 10]/[+m]]$

  b $[[\neg, \neg, \neg, 10, 9]/[-m]; [\neg, \neg, \neg, \neg, 9, 10]/[+m]]$:

  $[[0, 4]/[+s], [7, \neg, \neg]/[+s]; [\neg, 0, 4]/[+s], [7, \neg, \neg]/[+s]]$

$\boldsymbol{b'}$ $[[\neg, \neg, \neg, 0, 2]/[-m]; [\neg, \neg, \neg, \neg, 2, 0]/[+m]]$:

$[[0, 4]/[+s], [0, \neg, \neg]/[+s]; [\neg, 0, 4]/[+s], [0, \neg, \neg]/[+s]]$

$\boldsymbol{b''}$ $[[\neg, \neg, \neg, 2, 2]/[-m]; [\neg, \neg, \neg, \neg, 2, 0]/[+m]]$:

$[[0, 4]/[+s], [0, \neg, \neg]/[+s]; [\neg, 0, 4]/[+s], [0, \neg, \neg]/[+s]]$

$\boldsymbol{m_o}$ $[[\neg, \neg, \neg, \neg, 9]/[]; [\neg, \neg, \neg, \neg, 10]/[]]$:

$[[0, 4]/[+s], [7, 7, \neg]/[+s]; [\neg, 0, 4]/[+s], [7, 7, \neg]/[+s]]$

$\boldsymbol{m'_o}$ $[[\neg, \neg, \neg, \neg, 2]/[]; [\neg, \neg, \neg, \neg, \neg, 0]/[]]$:

$[[0, 4]/[+s], [0, 0, \neg]/[+s]; [\neg, 0, 4]/[+s], [0, 0, \neg]/[+s]]$

$\boldsymbol{b}$ https://deneeve.github.io/ac/ma/ex/432.b.mp3
$\boldsymbol{b'}$ https://deneeve.github.io/ac/ma/ex/432.bp.mp3
$\boldsymbol{b''}$ https://deneeve.github.io/ac/ma/ex/432.bpp.mp3
$\boldsymbol{m'_o}$ https://deneeve.github.io/ac/ma/ex/432.mpo.mp3

Figure 10: Example 4.3.2 with segmentations and musical forces assignments (b), harmonisations in C: *Harmonic Major*, *mode 2* and *mode 4* (b'), and key/degree uncertainty within *Ionic Major*, *mode 0* – with alternatives indicated by forward slashes – (b''), plus a minimal other harmonisation (m'_o)

Schlenker's minimal other, or rather one of them, consists in repeating the third and eighth notes, thus thwarting the semitone transitions between the third and fourth, and eighth and ninth notes, respectively. For Schlenker, the purpose of this and the other minimal other – which consists in lowering the fourth and ninth notes by an octave – is to see whether the semantic effect of the suggestion of the development of a phenomenon in stages (the sunrise) disappears. Here however, one of the two has been included for completeness, as the interest is in what musical forces may be assigned and what can be told given those, rather than to be able to precisely mirror Schlenker's idea of the development of a phenomenon in stages.[5]

In contrast to the preceding examples in this paper, in order to accomodate the segmentations of example 4.3.2, two different scales are needed, one for the first five notes plus another one for the remainder (with the semicolons representing the separation between the scales in the example).

Before stipulating the scales, the new $+s$ musical force in the example should be specified. It is related to resistance (definition 3.1.9) in that it similarly expresses 'not giving in to magnetism', except not by moving in the opposite direction, but by skipping (leaping) over it. So given a note n and a successor m, $[n, m]$ is upward skipping ($+s$) if there is a k such that $[n, k]$ is upward magnetic (definition 3.1.0.1) and leapwise (definition 3.1.4), and it is downward skipping ($-s$) if there is a k with $[n, k]$ leapwise and downward magnetic.

This extra musical force has been introduced not out of a conviction that it is needed per se in a comprehensive musical semantics based on Larson's forces, but to illustrate that one might define it with a view to (start) specifying the relationships between note pairs and sequences with distances larger than a step, and that this would potentially allow one to (monophonically) analyse a piece such as 'Zarathustra'. However, questions can be raised as to the status of such an analysis, as will become apparent.

Segmentation (b) is based on the assumption of two scale contexts, the first of which is known in jazz practice as *Phrygian* $\flat 4$, i.e. it is like the third 'Phrygian' mode of the standard major scale except it has a flattened 4^{th}. The second is called *Phrygian major*, i.e. it is also like the (minor) third mode of the major scale, except that it has a major instead of a minor third (see [Whi12], pages 5-6). In terms of definition 3.1.2 (scales), this means

[5] This despite that the minimal other's primary voice is only trivially stepwise.

Phrygian $\flat 4 = \langle HarmonicMajor, 2\rangle = [0,1,3,4,7,8,10]$, and *Phrygian Major* $= \langle HarmonicMinor, 4\rangle = [0,1,4,5,7,8,10]$, so except for semitone distances 3 and 5, the scales overlap, but additionally, they both contain the distance pairs $(0,1)$ and $(7,8)$, which account for the assignment of the $+s$ forces. Finally, the first scale has the pair $(3,4)$ leading to $-m$ while the second one has the $(4,5)$ needed for $+m$.

So while there is no single scale that can be built from a mode of the palettes *Ionic Major*, *Harmonic Major*, *Harmonic Minor*, or *Melodic Minor* (definition 3.1.1) to accomodate the note sequence of example 4.3.2, a pair of them can quite readily be found, upon which an analysis can then be constructed that precisely accentuates the difference between the two sequence halves, namely that one evalues to $-m$, and the other to $+m$, and plausibly even expresses the development of a phenomenon in stages.

But while this can deliver an analysis, the problem is that it does not seem to yield a plausible breakdown of the underlying harmony, nor a credible cognitive description of the listening experience. As for the first point, note that a chord or triad constructed from *Phrygian* $\flat 4$ (by stacking intervals of thirds) would amount to starting the piece in minor harmony, while the first half contains both a minor third (the 9) and a major third (the 10). And as for the second point, the intention of the composer, by having just a tonic and a fifth interval sounding, i.e. no major or a minor third, seems to be to leave the listener in the dark as to the character of the tonality.

What seems to be right though is that there are (at least) two palettes at play, just not the somewhat exotic harmonic major and minor modes specified above, and not split down the middle as the surface structure seems to suggest. Rather there appears to be an interplay between two modes of *F Ionic Major*, i.e. the fifth and first modes (palette indices 4 and 0), and the sixth mode (index 5) of *E*$\flat$ *Ionic Major*. This evaluates to *C major* (mode *V* of *F major*) for the first four notes, then a sudden switch to *C minor* (mode *VI* of *E*$\flat$) just before the halfway mark, followed by a return to *C major* before resolving to *F major* in a *V-I* cadential resolution. In example 4.3.2 (b'') the harmonic degrees are shown (sound as indicated is at `https://deneeve.github.io/ac/ma/ex/432.bpp.mp3`).

In [Sch19], section 6.2, Schlenker acknowledges the harmonic uncertainty in Zarathustra, stating that major or minor is initially 'underspecified', but does not consider the possibility of such 'underspecification' itself as being of semantic interest. Ultimately he settles on a sequence of musical events consisting in a *I-V-I* progression coupled with loudness (*ibid*, (23), page 66), which is mapped onto the sunrise event ((26), page 68), with the harmony being about stability, retreat, and a return to stability, and the loudness cast as rising luminosity, with its increase driving the idea of 'development in stages' But note that for Schlenker, the *I-V-I* progression is actually about the first three notes, which, in example 4.3.2 here, are considered to be part of a single chord. There (in (b'')), the *V-I* cadence takes place at the end.

Even though Schlenker's analysis nonetheless appears to capture the idea of the development of a phenomenon in stages, it does not do so in a way that seems to do justice to what seems to be a core feature of the note sequence, namely the surprise switch from major to minor harmony – right at the stage where major is actually established. This calls, at least, for a way to render musical events in terms of what seems 'normal' or expected, in order to encode deviation and surprise. But these are themselves not properties of observed events, but of how they affect the observer. Whether this requires a further level of description in terms of events of affect, and how that might relate to Schlenker's ideas of emotion in music as experienced events (*ibid*, section 10, page 86) remains to be seen.

5 Discussion

The aforegoing sections have been aimed at relating Schlenker's approach to musical semantics to Larson's musical forces, with a view to making the former more formal. One advantage of applying Larson's approach – while not strictly intended as semantic – to Schlenker, is the limited size of the note sequences that can considered. This obliges one to partition the sequences (i.e. create groupings), which is a convenient requirement as it aids the creation of the musical events that are to be mapped to external events. Schlenker does talk about musical grouping structure and their relation to events in [Sch19], but not until section 8.2, while the ideas on musical voices and truth are made precise in section 6.2, and the Zarathustra example appears even earlier (3.2). In other words, while some significant examples are given (including from Camille Saint-Sans and Frederique Chopin in sections 4.2 and 4.3), musical groupings are assumed, i.e. left to the musical intuitions of the (human) interpreter.

Here, Larson's constraint of assigning musical forces to points of harmonic stability has been used as a way to create segmentations, but it is also recognised that seemingly unstable points may be viewed as stable after all under different harmonic interpretations. See example 3.2.2 and beyond – and note that this particular example illustrates that semitone transitions in a scale may influence segmentations.[6] While the examples in this paper were all given in monophonic form, Schlenker's *Zarathustra* example (given as example 4.3.2 here) demonstrates that even in cases of polyphony, it depends on the amount of musical information present which interpretations might be possible (viz. the absence of the third at the start of the sequence).

While Larson's forces of gravity and inertia could in principle be assigned to leapwise as well as to stepwise instances, for magnetism and resistance they are restricted to stepwise sequences, and in [LV05] all patterns discussed are in fact stepwise. This plus another reason has prompted a focus on stepwise forces first and foremost, the other reason being Larson's idea that leapwise note transitions leave a memory trace to be resolved by a further note which is stepwise with respect to it ([Lar04], page 467). That has led to an approach here based on separating note sequences vertically first in order to leave a primary sequence that is stepwise, plus an auxiliary sequence that may or may not be stepwise, an idea which, as indicated in section 1.1, is also based on Pressnitzer et al. [PSS11] (page 5, figure 5): a sequence with leaps tends to be heard as multiple 'voices', which is in line with Schlenkers assertion that a single instrument may be responsible for several voices or virtual sources ([Sch19], page 37).[7]
This approach has obvious shortcomings, since there may be no straightforward way to assign forces to a leapwise residu of a vertical separation, or to a leapwise subsequence per se.[8] In example 4.3.2 (*Zarathustra*) an attempt was made to assign a 'skip' force, where there is a skip over an adjacent semitone interval, but it is at present unclear how to deal with leaps in general in the context of Larson's musical forces.

One reason why appears to lie in the assumptions underpinning Larson's

[6] Possibly this is in a similar sense as that, in the sentence *"I saw a man on a hill with a telescope"*, the reading in which the speaker used a telescope and saw a man on a hill might be prefered for semantic reasons, i.e. because of the link between *"too see"* and *"telescope"* – a reading which would not occur with, e.g. *"I saw a man on a hill with a sandwich"*.

[7] This is no coincidence, since both Pressnitzer et al. and Schlenker refer to the research area of auditory scene analysis, drawing on Bregman [Bre90].

[8] A further issue is the question how the difference between 'small' and 'large' intervals should be specified. Here it has been defined in terms of steps and leaps, but in Davids [Dav06] (page 27), large intervals are from a perfect fourth upward, citing evidence from Van Noorden [vN75] – however, the latter points out that the faster a note sequence, the smaller this crossover point tends to be (page 12).

work. As mentioned in section 3.2 here (in the context of example 3.2.1), Larson's theory – of melodic expectation as he calls it ([Lar04], page 458) – is based on the idea of stepwise completions or continuations of melodies by listeners under the influence of the forces of gravity, magnetism, and inertia. This is assuming an underlying alphabet, e.g. a scale, and a set of goals, e.g. the stable notes of a triad (cf. *ibid*, page 466, figure 1). Recall the *Zarathustra* example 4.3.2 which starts with an incomplete C triad, i.e. the third is missing so major or minor is left unspecified. If this were a cue for the creation of a completion by a listener in the sense of (*ibid*, page 469), then information for key/mode, i.e. scale/degree, would be assumed to be present. However, it is not until the transition of the fourth to the fifth note that the sequence gives in to magnetism, for which as indicated a single scale/degree might be assumed, but in fact the required semitone transition takes place precisely at the intersection between two scales. So if key and mode are to be represented as required in (*ibid*, page 469, point 1), then this representation would have to comprise at least both the possibilities of major and minor. For example, if the musical cue to be completed were the first two notes $[0, 4]$, then with minor belonging to the set of possibilities, $[0, 4, 5]$ could be predicted as a completion with $[4, 5]$ being upward magnetic. But as noted, what makes *Zarathustra* particularly powerful is how it delays giving away information about its tonality until the last possible moment, only to immediately change direction, and it should probably be this element of surprise one should want to encode in a formal semantic theory of music.

Beside this, *Zarathustra* could serve to illustrate some further (related) issues, concerning semantic links between voices, as well as dual group membership. As for the former, consider example 4.3.2 again, and note that there could be a group representing the *C major* harmony: $[0, 4, 7, 10]$, and one representing the magnetic pull to *C minor*: $[10, 9]$, with 10 being a member of both, since it plays a dual role in that it both establishes the tonality and is the subsequent pivot in sliding away from it. But this is particularly difficult to represent, because the 7 has been segmented into a different voice. Hence consider the following segmentation in example 5.1 below, of a stepwise instance – used before in examples 4.2.1 and 3.2.2). Rather than *A Harmonic Minor*, the example is given in *C Ionic Major* here, with (d) analogous to segmentation (c_1) in example 3.2.2 (but now for major), and (e) an overlapping segmentation.

Example 5.1. • $[4, 3, 2, 1, 0, -1, 0]$

a $[[4, 3, 2, 1, 0, -1, 0]/[+m]]$

d $[[4,3]/[g],[2,1]/[g,-r],[0,-1,0]/[+m]]$

e $[[4,3,2]/[g,-m,-i],[2,1,0]/[g,-i],[0,-1,0]/[+m]]$

e′ $[[4,3,0]/[g,-m,-i],[0,6,0]/[g,-i],[0,6,0]/[+m]]$

a https://deneeve.github.io/ac/ma/ex/51.a.mp3
e′ https://deneeve.github.io/ac/ma/ex/51.ep.mp3

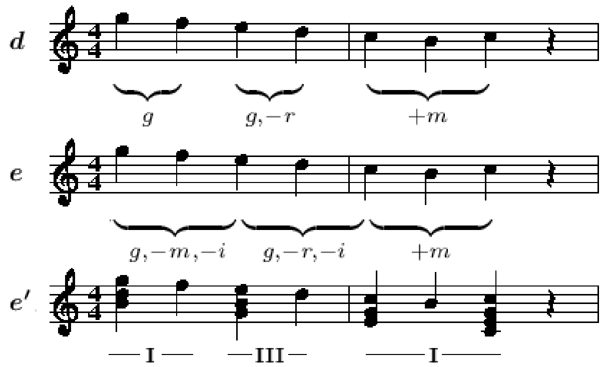

Figure 11: Example 5.1 in *C Ionic Major* with segmentations and musical forces assignments for d and e, plus the harmonisation given by e'

Segmentation (e) is a pseudo partition of the instance, where elements at the bounds of one group can also be members of an adjacent group. These are the third and fifth notes of the sequence – which was taken from ([Lar97a], page 63), example 6 (second row). There indeed the third and fifth notes appear pivotal in the sense that they feature as bounds of the three and five-note patterns which end up making up the eventual seven-note pattern. This follows the $abc \longrightarrow ab, bc$ decomposition in ([Sch19], section 8.3.1, page 77, (35)), which Schlenkers terms uneconomical, unless in cases of occlusion or overlap, with the latter being suited to cases of modulation according to the author. Modulation can be argued to occur here, though within the same rather than between keys,[9] and the harmonic motion could for instance be *I-III-I*, as it is in figure 11.

Equation 5.2 gives the musical events of example 5.1 (and figure 11) as a sequence of quintuples $\langle harmony, gravity, magnetism, resistance, inertia \rangle$.

Equation 5.2.
$M = \langle\langle III, g, -m, 0, -i\rangle, \langle I, g, 0, -r, -i\rangle, \langle I, 0, 0, 0, +m\rangle\rangle$

[9] A modulation between keys is, for instance, from *C major* to *G major* with the new (base) scale gaining a sharp ($f\sharp$) and G becoming a new first mode or degree, while within the same key there is no new sharp, and G is fifth degree of C.

Now again a *kite-landing* event sequence could be made consistent with the above musical sequence of events, taking Schlenker's overlap suggestion into consideration:

Equation 5.3.

$$\begin{aligned} \textit{kite-landing} = \quad \langle \textit{kite}, \quad & \langle\langle wind = strong, direction = down\rangle, \\ & \langle wind = none, direction = down\rangle, \\ & \langle wind = none, direction = none\rangle\rangle\rangle \end{aligned}$$

For equation 5.3, the harmonic order $III < I$ is used (as I is most stable), with the airborne positions, downward directions, and windlessness the common overlapping sub events. Then indeed it may again be said that *kite-landing* is true of the note sequence, albeit with a different – and because of the overlap arguably simpler – set of sub events comprising the main one. So examples 5.1 and 4.2.1 show, beside the potential upside of allowing pseudo partitions, how there could be different ways of assigning musical forces to the same piece in order to arrive at different specifications of the same event, or similar events.[10]

But note that obviously other events could be made true of note sequence of examples 5.1 and 4.2.1 (and 3.2.2) via equation 5.2, such as *boat-approaching* (see [Sch19], section 6.2, page 68, (26 c).[11] This would involve interpreting gravity and downward inertia in terms of continued motion towards an observer ashore – aided by the movement closer to an observer implied by downward magnetism – until there is minimal distance and stability is achieved. However, using equation 4.2.3 instead would involve the event being met with resistance ($-r$), e.g. from a retracting wave, and being propelled ($-m$) by an incoming one before coming to a standstill on the beach. The difference between the events is then in complexity rather than nature, and the semantics should reflect this by allowing the more complex event to entail the simpler one.

Note that the upward magnetism in the last musical event of equation 5.2, $\langle I, 0, 0, +m\rangle$, implies, according to definition 4.1.2 (b ii), that the kite is to land further from the observer relative to its initial position, due to adopting Schlenker's association of higher pitch with smaller size, and hence, derivatively, greater distance. This feels unsatisfactory in that resolution may be more aptly cast in terms of a return home (closure), and so the inference

[10] It must be noted that example 5.1 was redered in a different scale, but arguably *kite-landing* of equation 4.2.3 is also consistent with example 5.1 (d).

[11] But not, for instance, *car-crash*; (26 e) in [Sch19].

of increased distance just because resolution happens to be to a higher note does not seem quite right.

Be this as it may, the examples above, including those in the preceding sections, have demonstrated how segmentations and/or partioning of note sequences together with the application of Larson's musical forces, allows note sequences to summarised into events. Seemingly one advantage of this is not only obtaining these events, but in the process bypassing an assumption underpinning Schlenker's work noted by Migotti and Zaradzki [MZ19], namely that each note is to be interpreted as an event.

That said, the current study has not unearthed many common building blocks from the relatively simple note sequences considered, except those of motion to stability as guiding the grouping process and hence the resulting events. However, what may be considered stable in a monophonic sequence appears to be contingent on the way the sequence is heard harmonically, which likely depends on examples of polyphony a listener has been exposed to. But as the *Zarathustra* example shows, even in cases of polyphony it is not always clear what the harmony is supposed to be, and it may well be the case that this should not always be clarified in order to determine musical meaning, but rather that unclarity may in fact part of the meaning.

6 Concluding remarks

In this study, Larson's musical forces of gravity, magnetism, resistance, and inertia, have been applied to Schlenker's musical semantics in order to summarise the pitch information into musical events, which can then in turn be mapped to external or world events. It was found that even short musical snippets can be given sometimes complex yet plausible interpretations with respect to their harmonic motion, which influences the way a note sequence is partitioned, and what (world) events may subsequently be derived from them.

Schlenker uses various features of the music at hand beside pitch, including harmony, loudness, rhythm, silence, and timbre, with the relevance of these characteristics to be determined by a human evaluator who ultimately decides on, and demonstrates, what the musical meaning is, in terms of external events, by drawing inferences using the available features that are coherent such that a resulting compound event can be said to be true of the music. Here, an attempt has been made to focus purely on pitch, by considering simple short melodies simple melodies with a regular meter. However, certain assumptions regarding common harmonic motions were made and applied to the example melodies, as it appeared implausible to assume a listener would experience them as if they would be accompanied by merely a single chord. So effectively pitch and harmony have been (mostly) looked at in combo.

The resulting segmentations, having given rise to representations of force-based events (in the sense of Larson), were then used to draw structure-preserving (licensed) inferences about a music-external world, as Schlenker requires for a 'bona fide' semantics of music. For music that is more complex than just a regular monophonic line, it is conceivable that Larson's forces could act as constraints on the licensed inferences.

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