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Larson's Musical Forces in Schlenker's Music Semantics

Abstract: Larson's musical forces of gravity, magnetism and inertia link music to metaphors of physical motion. Schlenker's music semantics is based on similar physical world associations. Because Larson's forces are about note movements towards harmonic stability, his framework implies note groupings at stable boundaries, given common cadential harmony. These groupings with forces assignments can then be viewed as musical events in Schlenker's approach, and mapped to structure-preserving external (world) events as required for this author's semantics. To this end, Schlenker's truth definition, specifying when an event is 'true of' a musical expression, will be adapted. The synthesis amounts to what Schlenker argues for: a formal semantics of music, albeit limited to melodic lines confined to a single key.

1. INTRODUCTION

This paper's aim is to connect Philippe Schlenker's (2019) music semantics with work on so-called musical forces by Steve Larson (1997a). Both establish metaphorical links between music and the physical world. In Schlenker's case musical features are associated with events or situations in the world, while Larson relates musical pitch motion to physical motion. This suggests that, at least for pitch and harmony, the approaches can be linked, in the sense that Larson's musical forces can be used to constrain Schlenker's semantics, or that Larson's framework can be interpreted within that of Schlenker. Both approaches are broadly explained below, and concepts used by the authors will be formalised in subsequent sections.

The reasons for explicit formalisation are as follows: first of all Schlenker sketches a broad framework but only voice and musical truth are defined. Secondly, while Larson's approach is narrower in the sense of being more about individual note movements, his forces tend to be described rather than defined. Finally, with the status of music semantics as yet unclear – e.g. should it depend on how a listener interprets music or not? – Hamm, Kamp, and Van Lambalgen insist that in either case, a semantics should be explicitly formalised, *"to ensure the computability which is fundamental to cognition"* (Hamm et al. 2006, 3).

1.1. Schlenker's music semantics

Schlenker's *Prolegomena to Music Semantics* (2019) 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 (*ibid.*, 36). The basic idea is that inferences are drawn about actions or features of so-called virtual sources (after Bregman 1990), which are imagined to be responsible for or represent the music's sounds. For example, lower-pitched sounds might be associated with larger entities, and if the sound gets louder (crescendo) then it may be infered that the entity or entities are getting closer (viz. Schlenker 2019, 50-52). As Schlenker puts it, music semantics starts as sound semantics. See Figure 1 for an example of the latter feature.[1]

Figure 1: Mahler's *Frère Jacques* – First Symphony, 3rd movement, example 12 b (with added crescendo) in Schlenker 2019, 51, sound: bit.ly/2m9WnIS

Schlenker remarks that because of the crescendo, the piece could be interpreted as an approaching procession, which, as the author adds, is intended to be playing funeral music according to the composer (Gustav Mahler). The score in the figure shows two instruments, or voices, which may be associated with two virtual sources, in this case percussion (timpani) and bass.[2] The idea here is that the first source is responsible for the procession inference, and the second is self-referential in that its inference in this case is simply the music itself.

This particular example is intended to illustrate the effect of the crescendo, loudness being one of several properties of music about which one could in principle draw inferences. It is not difficult to imagine that if the music were instead to go softer (descrescendo), then it would rather represent a procession moving away (as in ex. (12c), *ibid.*, 51).

Like loudness, pitch and harmony are also properties or features of music about which inferences might be drawn, and it is these that this paper is focused on. Similarly, rhythm and velocity or speed are musical features. In the main examples of this paper, the latter will be kept largely regular and constant, while pitches will be mostly kept within an octave, i.e. the chief aim is to consider the interaction of notes within relatively small tonal intervals, rather than to look at pitch in the sense of 'very high' vs. 'very low' – which as noted is another way of considering pitch as a feature, but from the above 'sound semantics' rather than a 'tonal' perspective. That said, sound semantics will not be completely ignored but the primary focus is tonal.

Figure 2 is an example from Schlenker 2019 where tonal inferences are used, showing the score of the beginning of Richard Strauss' *Also Sprach Zarathustra*, which Schlenker links with Stanley Kubrick's 1968 film *2001: A Space Odyssey*, where this music is used. The author's aim is to explain why the music is appropriate for the motion picture's imagery. Essentially, this boils down to the claim that a description of the events depicted in the imagery qualifies as one of the snippet's possible denotations.[3]

The concept of possible denotation is defined by Schlenker on p. 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 $e_1, \ldots, e_n$.*

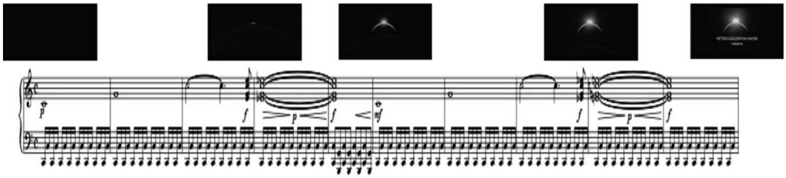

Figure 2: Opening of Strauss' *Also Sprach Zarathustra* annotated with imagery from Kubrick's *2001: A Space Odyssey* (ex. (6) in Schlenker 2019), video: bit.ly/2DfiE3m

This definition assumes a voice (associated with a virtual source) is split into n musical events, posits an object O, and then says that for each event m_i there is an (imagined) event e_i in the world in which O participates. The resulting event sequence may be considered as the music's denotation (or meaning) in case it is 'true of' the music.

Each m_i can contain a number of features about which inferences may be drawn. For *Zarathustra*, Schlenker considers two: harmony and loudness. The analysis being limited to the first three measures, he renders the musical events as $M = \langle\langle I, 70db\rangle, \langle V, 75db\rangle, \langle I, 80db\rangle\rangle$, i.e. as the author has it, the harmony moves from stable to less stable and back again, while loudness increases. The idea is that there is a corresponding sequence of virtual or imagined events which can be said to be 'true of' the music, and Schlenker gives the following definition to make this precise (Schlenker 2019, 67 – note that things will be further clarified in Section 3).

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*
   (1) *O has less energy in e_i than in e_k; or*
   (2) *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 would allow for the denotation *Sun-rise* = ⟨*sun,* ⟨*minimal-luminosity, rising-luminosity, maximal-luminosity*⟩⟩ to be true of M, but as Schlenker points out, there are more options, e.g. *Boat-approaching* = ⟨*boat,* ⟨*maximal-distance, approach, minimal-distance*⟩⟩, while their opposites *Sun-set* and *Boat-departing* are among the denotations that do not qualify (*ibid.*, 68).

Musical meanings in Schlenker's view then, are the possible denotations that are true of the musical events, or the 'world' events that qualify given Definition 1.1.2. But note first that his methodology involves the construction of an adaption of the music where one element is altered in order to demonstrate the semantic effect ('minimal pairs', cf. page 56), e.g. repeating the same note in *Zarathustra* instead of having a rising pattern would thwart the sunrise impression. Secondly, Schlenker emphasises that any meaning thus obtained is merely one among many possibilities (page 67). This is presumably because the information music conveys is more abstract than language (page 36).

The above points to some underlying presuppositions in Schlenker's music semantics: meaning is truth-conditional and extra-musical, i.e. music is about some reality that is external to itself, in other words, it is not about harmony or associated properties of tension (instability) and relaxation (stability) which would be an 'internal' semantics, neither is it about expectations or emotions that might be aroused within the listener. Rather it is a structure-preserving mapping between musical events and events in the world.

1.2. Larson's musical forces

In Larson's *Musical Forces and Melodic Patterns* (1997a) it is claimed that the way (experienced) listeners hear music is aided by three metaphorical musical forces: gravity, magnetism, and inertia. The idea is that because of these forces, music is heard as purposeful, because they link music to phenomena that are familiar from the physical world.

Larson specifies the forces as follows. Gravity is a note's tendency to descend given some stable threshold or ceiling, magnetism is the tendency to be attracted to a (more) stable pitch, and inertia the tendency of notes to continue in the same pattern. Larson's basic idea is that a piece of music may be viewed (or rather heard) as having been constructed level by level, from a simple level with stable notes to a more complex one that may have less stable notes as well. The more complex levels are called embellishments, and the transitions from lower to higher levels are controlled by the forces (Larson 2004, 457), with the *"increasingly more-detailed levels leading ultimately to the piece itself"* (Larson & VanHandel 2005, 132).

Figure 3 below (with sound file links as elsewhere)[4] is a simple example to illustrate this idea as well as Larson's three forces. The basic first level, containing the notes *[e, c]*, has motion from the mediant (or 'third') to the tonic, which are both stable. At the more complex second level, these notes have been embellished with the less stable subdominant (the 'fourth') and supertonic (the 'second'), ultimately obtaining *[f, e, d, c]*.

Level 1:
4321.1.mp3

Level 2:
4321.2.mp3

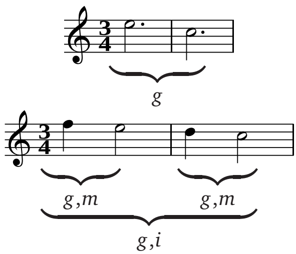

Figure 3: Embellishing to *4-3-2-1*

The whole sequence is an example of gravity (marked *g* in the figure) for its downward motion (both levels), and of inertia (marked *i*, level 2) because of continued motion and pattern repetition: *[f, e]* is reproduced in *[d, c]*. These sub sequences (again at level 2) are also gravitational. Moreover they are magnetic (*m*) since the less stable *f* is attracted to the more stable *e*, and the less stable *d* is similarly attracted to the (most) stable *c*. But note the attraction *[f, e]* is stronger, since these notes differ by a semitone, while the final two notes are a whole tone apart.

Larson staged prediction experiments to test the psychological reality of his forces, e.g. in *Measuring Musical Forces* (Larson & VanHandel 2005), where subjects were presented with cues and asked to predict the next note. Similar to the Figure 3 example, they might be given the middle two notes *[e, d]*, and asked to complete the pattern. In case the answer is *c* (viz. *ibid.*, 122), the pattern is said to 'give in' to gravity as well as inertia. It should strictly also give in to magnetism, but Larson eventually preferred to restrict this to semitone attraction in Larson 2002 and beyond (see page 381, footnote 6).

In Larson & VanHandel 2005, patterns or note sequences are stepwise (viz. Definition 3.1.4 here), meaning the next note always differs by at most a whole tone (page 121). Stepwise motion is considered central to musical perception in Larson's view; in case larger intervals (i.e. leaps) occur, the listener is left expecting a stepwise completion (Larson 1997b, 105-6). See Figure 4 for an example with leaps, that leads to a stepwise connection (completion) between the first and last notes.

leap.trace.mp3

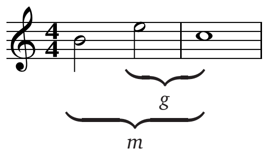

Figure 4: Displacement of a trace

In this figure, the interval between the first two notes *[b, e]* is a fourth, leading to a 'trace' on the *b* in the listener's mind that gets 'displaced' in the author's terminology, upon hearing the final note *c*, as the interval *[b, c]* is stepwise (a semitone). The idea is that the listener hears this interval, or is aware of the connection between these notes. The last two notes could be viewed as base level, and the first, being less stable, as an embellishment, i.e. the basic structure is given by gravity, with the first and last notes subsequently connected by magnetism.

The example illustrates how forces may be assigned at multiple levels, and indicate (or 'control') musical motion towards more (harmonic) stability. This implies that forces may be assigned at such points in a partioning of musical events, and that such events may be analysed hierarchically. This in turn implies the possibility of a music semantics with at least a compositional flavour – despite Schlenker's claims about *"a source-based semantics rather than a compositional semantics"* (Schlenker 2019, 39).

1.3. Plan for the rest of the paper

The remainder of this paper will be organised as follows. In Section 2, Schlenker's and Larson's conceptions of semantics are described. Then in Section 3, Larson's forces are used as an abstract stage in the analysis of a few melodic patterns, from two of his papers, where force assignments are mapped to events which can be considered as denotations for Schlenker's semantics. This will involve the specification of several formal definitions, the chief aim being the extension of Definition 1.1.2. Subsequently, in Section 4 the resulting framework and its merits are discussed, including philosophical issues around event semantics and compositionality. Additionally some alternative views on music semantics are considered, including Meyer's (1956), and what those ideas might entail for musical meaning. Finally in Section 5, the conclusions of the paper are summarised.

2. SCHLENKER'S AND LARSON'S NOTIONS OF MEANING

While Schlenker has an explicit programme geared towards the semantics of music, this is not the case for Larson, who does not even mention meaning very often. Larson views musical meaning as a suggested quality of music, such that it allows a listener to experience feelings, action, or motion (Larson 1997b, 101). According to the author, such suggestions arise in perception because of the interplay of his musical forces, which are viewed as musical motion that is in turn 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, with y an assigned meaning, for example an ascending gesture (*ibid.*, 102). There may be a complex interplay between musical elements for meanings to emerge, for instance a *C* below the magnetic pull from *F* to *E* is not part of the musical force as such, but it does give it context by providing information that the melody has landed on the stable third of *C Major* (page 131).

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

For Schlenker on the other hand, musical meaning and semantics is the core concept in Schlenker 2019. 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 (viz. Schlenker 2018, 366), and consequently, he suggests formal semantics could be developed for representational systems including pictures, gestures, music, or dance.

Beside his portrayal of music semantics as truth-conditional as well as part of a wider theory, Schlenker also attempts to characterise it within the classic (semiotic) Peirceian tripartition (Peirce 1998), where signs can be iconic, indexical, or symbolic. He claims musical signs may be considered as indices because his semantics results from positing causal relations between sound and (virtual) sources (Schlenker 2019, 37). But he does admit things may not be so straightforward: a musical sign could also be viewed as iconic if it resembles its denotation, which hangs on how one views the concept of resemblance.[5] According to the author, a sufficiently abstract notion of iconicity could make the sunrise denotation of Figure 2 iconic since it fulfills structure-preserving conditions (his truth definition (Def. 1.1.2)), which could then be viewed as satisfying the idea of resemblance – even if a sunrise is not a sound-producing event (*ibid.*, 74). Possibly, adding Larson's forces to the mix will push the semantics more in the direction of iconicity if this then means that musical motion more closely resembles the resulting denotations.

A notable difference between Schlenker and Larson is how they view the direction of the mapping between musical and physical space. The idea behind Schlenker's truth definition is to specify a structure-preserving mapping between musical and physical events. Larson on the other hand says that physical gesture is heard as a mapping onto musical space. Essentially, both are talking about a homomorphism between two spaces, i.e. a structure-preserving mapping. Nevertheless, there may be an interesting if subtle difference in emphasis. As noted, Larson's claim with respect to his forces is that these control how experienced listeners hear music, while there is no such restriction for Schlenker, so plausibly for Larson, there is an accent on 'active' listening (viz. his focus on prediction), and given the embellishment levels (Figure 3) even on the compositional process itself. The difference in direction then, might be compared to the difference in linguistics between production (Larson) and comprehension (Schlenker).

3. LARSON'S FORCES IN SCHLENKER'S SEMANTICS

In the present section, Larson's forces will be made (more) precise, and assigned to a few simple musical examples, including a stepwise example as in Figure 3 but also a leapwise (i.e. non-stepwise) one, like in Figure 4. The idea is that by ascribing forces at points of harmonic stability, a partitioning of the example into musical events ensues. These events are treated as features, i.e. they have the same form as Schlenker's events such as where he reduces a piece to its loudness in decibels and harmonic motion (see Section 1.1, and Schlenker 2019, 66).

Here, harmonic motion will also be a feature due to Larson's reliance on scales and degrees (viz. Larson 1997a, 59), which is because of said stability considerations. The events thus obtained may, like Schlenker's musical events, be viewed as abstract states of affairs, with which a potentially large number of situations in the world could possibly be consistent. Examples of such states of affairs in the world will be given, involving a virtual source and events the source participates in, given an adapted version of Schlenker's truth definition (i.e. Definition 1.1.2).

To begin with, definitions for scales, note sequences, harmonic role substitutions and stability are given. This is to be able to give musical examples in terms of numerical sequences, which can then be partitioned at their points of stability because, according to Larson, this is where his forces 'control ' the music towards. After this, the forces themselves can be defined, to be assigned to these partitions in a first concrete musical example. Finally, mappings will be specified from the resulting musical events to 'world' events. Note that these mappings will be stipulative, i.e. based on intuitions about the relation between music and the world.

But first for the sake of illustration, two well-known scales are the major and minor scales. They are shown in Figure 5, and are *C Major* and *A Minor* respectively. The latter was picked to highlight their relationship: *A Minor* may be constructed by starting on the sixth note of *C Major*, and it is consequently also known as mode `VI` of the key of *C Major*. Sound files (mp3) are linked in the figure, and the scales are ended with their triads (chords), which are the first, third and fifth notes sounded together – which are also Larson's points of stability.

Figure 5: The *C Major* and *A Minor* scales with their triads

The numbers at the top of the figure are to indicate how so-called note positions are represented here: as 0-based numerical lists, i.e. the root of the harmony gets the number 0, and so what was earlier specified as being stable first, third, and fifth notes, will be rendered as numbers 0, 2, and 4, respectively. This is to enable modular or clock arithmetic (division remainder), since the final note 7 is the first one repeated an octave higher, and $7 \ mod \ 7 = 0$. The effect is that one can continue to count into higher – or lower – octaves, e.g. in the coming example the note below the root is used, rendered as -1, and $-1 \ mod \ 7 = 6$.

A first example, more comprehensively analysed later, is adapted from Larson 1997a (where it is example (5), pattern 2), and is shown in Figure 6 below, with forces assignments as well as harmonic motion. In the following section, elements of musical structure are defined formally, and illustrated with aspects of this example.

The first row of numbers are note positions as above, and the second row are their so-called relative scale degrees. The Roman numerals are scale modes to which these degrees are relative, as will be explained. The forces gravity (g), magnetism (m) and inertia (i) are assigned based on these relative scale degrees on the second row, i.e. to note groups with stable endings (0, 2 or 4, as indicated above).

lar52.mp3

lar52.v-i.mp3

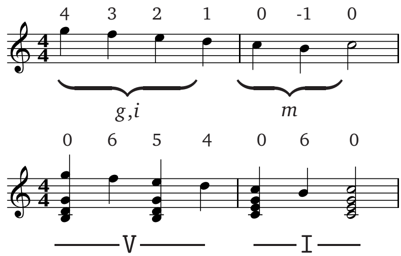

Figure 6: Larson's example (5.2) from Larson 1997a

3.1. Musical structure

Scales, sequences and triads Scales are essentially given by structures indicating the number of half steps (or semitones) from the starting note (root). The spaces or intervals between the notes of a scale are usually either a whole or a half step, e.g. *C Major* above has half steps between notes 2 and 3, and between 6 and 7, while *A Minor* has them between 1 and 2, and 4 and 5 – with the remaining intervals whole steps (two semitones).[6]

But in order to produce a concrete scale description from such ratios, a collection of pitches is needed.

Definition 3.1.1. *A pitch collection is a 12-element list of pitch names. The one used here is* $P = [c, c\sharp, d, d\sharp, e, f, f\sharp, g, g\sharp, a, a\sharp, b]$*, with the following enharmonic ('same-sounding') equivalences:* $c\sharp = d\flat, d\sharp = e\flat, f\sharp = g\flat, g\sharp = a\flat$*, and* $a\sharp = b\flat$*. These equivalences may be substituted for each other. Pitches may be referred to by their (0-based) indices, e.g.* $P[4] = e$*.*

While it is possible to generate the minor scale from the major scale since it is one of its modes (illustrated in Figure 5 – which more generally holds for other scales as well), this is not done here. Instead, the so-called scale measurements used in this paper are given 'hard-coded' as distance lists instead.

Definition 3.1.2. *A scale measurement is a 7-element list of semitone distances counted from the first element, or root*(0)*. Specific measurements are firstly Ionic Major* $= [0, 2, 4, 5, 7, 9, 11]$*, Lydian Major*

$= [0,2,4,6,7,9,11]$, *Mixolydian Major* $= [0,2,4,5,7,9,10]$*, and Aeolian Minor* $= [0,2,3,5,7,8,10]$*. The latter three are respectively modes 3, 4, and 5 of Ionic Major. Secondly there is Harmonic Minor* $= [0,2,3,5,7,8,11]$*, and Melodic Minor* $= [0,2,3,5,7,9,11]$*. These are derived from Aeolian Minor by respectively raising the last note, 6, and additionally raising note 5 as well. Except for the first, called prime, intervals in scales are named after their ordinals. If the third has distance* 3*, the scale's aspect is minor, if this is* 4 *it is major.*

Note that even though the definition gives harmonic modes as 0-based numbers as this is computationally convenient, in the musical examples harmonic motion is given in traditional (1-based) Roman numeral notation (as in Figure 6). So in the sequel, if `V-I` motion is indicated (candential motion as explained later), then this may be considered as shorthand for $mode(4) \rightarrow mode(0)$.

With pitch collections and scale measurements, concrete scales can be produced:

Definition 3.1.3. *A scale instantiation or simply scale is generated from a pitch collection P and scale measurement M as follows. Pick a root pitch $P[r]$, and fill a list S as follows. For each $i = 0 \ldots 6 : S[i] = (M[i] + r)\ mod\ 12$.*

This will generate the *A (Aeloic) Minor* scale in Figure 5 from $P = [c, c\sharp, d, d\sharp, e, f, f\sharp, g, g\sharp, a, a\sharp, b]$ and $M = [0,2,3,5,7,8,10]$ as follows: the root pitch is $P[9] = a$, so the indices for picking the pitches from P are $[9,11,12,14,16,17,19]\ mod\ 12 = [9,11,0,2,4,5,7]$, so $S = [a, b, c, d, e, f, g]$.

While this may all look rather involved, the purpose is to later be able to compute Larson's forces, particularly magnetism, from a given scale plus a note sequence. In Figure 5 the note sequence for the above scale was given as $[0,1,2,3,4,5,6,7]$, which as indicated is the scale plus its root repeated an octave higher. It is also the indices mod 7 for the pitches in S above. Since $7\ mod\ 7 = 0$ (i.e. 7 has degree 0; see below), the pitches in the figure are $[a, b, c, d, e, f, g, a]$.[7] A note sequence in general is specified as follows.

Definition 3.1.4. *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. In case for each adjacent position pair,* $abs(p_1 - p_2) = 0$ *or 1, the sequence is stepwise. For any position p, its degree is given by* $p \bmod 7$*. Degrees are traditionally called tonic, supertonic, mediant, subdominant, dominant, submediant, and subtonic.*

As indicated, the idea is that note sequences are to be partitioned with forces assigned at points of stability, but before that concept can be made precise, triads (or chords), chord progressions and cadences (a special kind of progression) should be defined, since stability also applies to these. This will then applied to Figure 6's harmony to illustrate things further, after the following definition.

Definition 3.1.5. *A triad is a list of three note degrees* $[d_0, d_1, d_2]$ *with* $(d_1 - d_0) \bmod 7 = (d_2 - d_1) \bmod 7 = 2$ *(in traditional terms they differ by the interval of a third). The above order being termed* root position*, the order* $[d_1, d_2, d_0]$ *is called the* first inversion*, and the order* $[d_2, d_0, d_1]$ *the* second inversion*. Given a scale S, the triad's* aspect *can be determined: this is given by* $(S[d_1] - S[d_0]) \bmod 7$*, which is the number of semitones between* d_0 *and* d_1*. This may be 3 or 4. In the first case the aspect is* minor*, in the second it is* major *(these intervals are called minor and major thirds). The root* d_0 *gives the triad's* mode*, and it is customary to use this to represent a triad as a 1-based Roman numeral (i.e.* $d_0 + 1$*), usually written in capitals though frequently in lower case if the underlying scale is minor.*

The harmonised part of Figure 6 is repeated below as Figure 7, to help illustrate triadic harmonic motion as just specified.

lar52.v-i.mp3

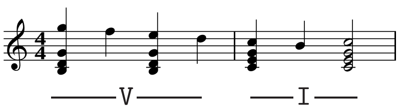

Figure 7: Larson's example (5.2) from Larson 1997a harmonised

According to Schlenker cadences in the form V-I are typically used to end a piece (Schlenker 2019, 59), and to assume that here, there are two ways to arrive at the respective triads (chords) in the above figure.

In both cases, the last triad is mode 0 (i.e. I) of the *C Ionic Major* scale, and given a triad is constructed from the stable tones $[0,2,4]$ and that *C Ionic Major* $= [c,d,e,f,g,a,b]$, the final triad is the tonic triad in root position: $[c,e,g]$. Then V is based on the *Mixolydian Major* scale, which has $[0,2,4,5,7,9,10]$ as its measurement, so given pitch collection $P = [c,c\sharp,d,d\sharp,e,f,f\sharp,g,g\sharp,a,a\sharp,b]$, find $\mathtt{V} = mode(4) = g$ in *C Ionic Major*, which is $P[7]$, and which generates *G Mixolydian Major* $= [g,a,b,c,d,e,f]$ according to Definition 3.1.3. Then using the stable tones $[0,2,4]$ in first inversion $[2,4,0]$ yields the triad $[b,d,g]$ as it appears in the figure.

An easier way to get from I to V is to use the stable tones $[0,2,4]$, and note that since $\mathtt{V} = mode(4)$, the new triad tones are the old ones $+4 \ mod \ 7 = [4,6,1]$, or $[6,1,4]$ in first inversion position, yielding $[b,d,g]$ directly from *C Ionic Major*.

Harmonic motion and substitution The previous Definition 3.1.5 clarified how triads may be built on any note of a particular scale, and that scale as well as starting root may determines a chord's character. But the subsequent example underlined that what makes triads or more generally harmony interesting, is its motion. To make this more precise, the concepts of progression and cadence – which were illustrated above – as well substitution, are specified below in order to describe the effect of progressions on note degrees. This will end up modifying Larson's conception of triadic stability.

Definition 3.1.6. *Given a scale S, a triad series T is the list of triads using all the scale's degrees* $0,1,\ldots,6$ *as modes, so* $T = [[0,2,4],[1,3,5],\ldots,[6,1,3]]$*, or in Roman numerals,* $[\mathtt{I},\mathtt{II},\ldots,\mathtt{VII}]$*. A progression is any sequence of triads drawn from some scale's triad series. A cadence is a progression which ends on the modes* $[4,0]$*, or in convential Roman numeral notation, on* V-I.

The notions of progression and cadence are more general in music theory than above, since a progression is not limited to having chords relative to a single scale: it is possible to use so-called modulation and switch to a chord drawn from a different scale. Furthermore, there are cadences that do not end on I, notably the so-called deceptive cadence – this 'pretends' to end on I, i.e. to *resolve*, but then serves up VI instead (see Schlenker 2019, 59). Nonetheless, the concepts as specified are as they will be used here, for the sake of simplifying the musical domain.

While the examples in this paper are essentially single (monophonic) musical lines, it is assumed that they are heard harmonically, i.e. that in perception the listener imposes a harmonic structure over them, with a preference for cadences, as already suggested in Figure 7's harmonisation. This implies that the listener internally fills in sounds not physically present, a process Larson calls auralisation (Larson 2004, 467) – plausibly because exposure to music has led to particular expectations. Figure 8 shows the previously introduced melody again, with its note sequence and cadential harmony, in order to illustrate how the latter modifies the former.

lar52.mp3
lar52.v-i.mp3

Figure 8: Larson's example (5.2) from Larson 1997a with harmonic substitutions

The note sequence in Figure 8 is in the form 'position/relative' (cf. Figure 6), as the usual note degrees undergo a substitution, i.e. take on a different role, given a harmonic mode different from mode 0. Finding such a relative note role involves modularly subtracting harmonic modes from the absolute note degrees. For instance, for the fourth note in the example, 4 tonal steps are needed to get from C to G (i.e. from I to V or mode 0 to 4), and subtracting this (modulo 7) from the old degree 1 gives the new role 4. This is specified below, where for the above figure, the note sequence N is $[4,3,2,1,0,-1,0]$, the harmonic sequence H is $[4,4,4,4,0,0]$ (i.e. $[\mathtt{V},\mathtt{V},\mathtt{V},\mathtt{V},\mathtt{I},\mathtt{I}]$), and the resulting substitution R_s is $[0,6,5,4,0,6,0]$.

Definition 3.1.7. For a note sequence N and accompanying harmonic sequence H, the *modal role substitution sequence* R *is a list of pairs* n/s *such that for each* $n \in N$ *and its associated* $h \in H$, $s = (n-h)$ *mod* 7. R *may also be given as* R_s *with just the substitutes.*

That given the above, the fourth note in the figure might now be viewed as having degree (role) 4 rather than 1 is significant, because as indicated this is a degree that Larson considers stable (see the paragraph following Figure 5). This concept is looked at next in more general terms.

Tonal and harmonic stability As indicated in Section 1, a central notion for Schlenker and Larson is stability. For the latter this is firstly due to motion of gravity and magnetism towards more stable notes, but also because embellishments at higher levels tend to have less stable notes, i.e. as Larson would have it, musical compositions are constructed towards having more instable notes present. Neither author gives unambiguous (i.e. total) orderings from least to most stable, but both give some clues for the degrees – the notes within a scale – as well as for the chords (triads), i.e. for the modes. This is explained below, and the definition following it will be treated as what Schlenker calls 'pitch space'.

It should firstly be noted that total orderings of tonal and harmonic stability may not ultimately be realistic, but their existence is assumed here to make the mappings from musical to physical events more straightforward. Furthermore, Larson makes a distinction between inherent and contextual stability (viz. Larson 1997b, 106), which is not made here – stability in this paper is Larson's inherent stability.

First of all the tonal degrees.[8] According to Larson, the tonic, mediant, and dominant are most stable, i.e. the notes of the major tonic triad (Larson 1997a, 59), while the subtonic is (inherently) unstable (Larson 1997b, 128) and dissonant. Moreover, the subdominant is considered less stable than both mediant and submediant (*ibid.*, 111). Additionally, Larson remarks that the dominant is particularly stable. That leaves the supertonic, plus some educated guesses. Assuming the subtonic is the most unstable because its triad contains an inherently unstable tritone interval (also known as 'flat fifth'; *ibid.*, 110),[9] the supertonic should be somewhere between subtonic and submediant, which leaves the question whether the subdominant is more or less stable than the supertonic. It is arguably unstable since it is known as an 'avoid note' that signals change to the harmony, i.e. modulation (viz. Honshuku 1997, 14), so it will be considered second-least stable.

Secondly, the harmonic modes, for which it is Schlenker that gives several clues in Schlenker 2019. On page 59 he gives the Roman numeral ordering IV < V < I due to the common occurence of IV-V-I cadences, because *"this provides a gradual path towards tonal repose"*, but also notes that substituting VI for I in the aforementioned deceptive cadence results in lower stability, which implies VI < I, and so (among others) VI < IV < V < I. Moreover, on the next page the author mentions the so-called perfect cadence II-V-I, which similarly implies II < V < I. In minor scales however, the perfect cadence would be given by the modes VII-III-VI, i.e. VII < III < VI is also obtained. This implies VII < III < VI < II as well as VII < III < II < VI, but the latter is prefered according to Krumhansl's harmonic hierarchy (Krumhansl 1983, 46).[10]

The above may then be combined into the following for tonal and harmonic stability orderings:

Definition 3.1.8. *For note degrees (or roles) within a scale, the following tonal stability ordering is adopted:* $O_t = 6 < 3 < 1 < 5 < 2 < 4 < 0$. *In traditional terms, this means that subtonic < subdominant < supertonic < submediant < mediant < dominant < tonic. For triad modes built on a scale, the following harmonic stability ordering is used:* $O_h = 6 < 2 < 1 < 5 < 3 < 4 < 0$*, which written traditionally, means* VII < III < II < VI < IV < V < I.

Alphabets and levels Finally before giving the example of Figure 6 in full, the basics of levels of embellishment are specified. A brief example was already given in Figure 3 of Section 1.2. The core idea is that a musical line is constructed at a given level by choosing notes from a so-called reference alphabet such that they move to notes specified at a more basic level that have in turn been picked from a goal alphabet. This is a proper subset of the reference alphabet which contains notes that are more stable.

As mentioned in Section 1.2, Larson's view of musical composition is that it is built up as several levels of embellishment *"leading ultimately to the piece itself"*. Formally, two levels may be viewed as constructed from an overlapping sequence of embellishing pairs. Taken together, things may then be specified as follows.

Definition 3.1.9. *An alphabet is a set of note degrees for a given scale. If* G *and* R *are alphabets while* $G \subset R$*, and* G *has more stable degrees* *(which may be modally substituted) than R, then R is called a reference alphabet, and G a goal alphabet. The pair* (G,R) *is called an embellishing alphabet pair. In an embellishing alphabet sequence* $[S_1,\ldots,S_n]$*, each* (S_i,S_{i+1}) *is an embellishing alphabet pair.*

3.2. Musical forces

Figure 9 shows Larson's example (5.2) from Larson 1997a built up in three levels, with forces assignments as well as harmonisation.

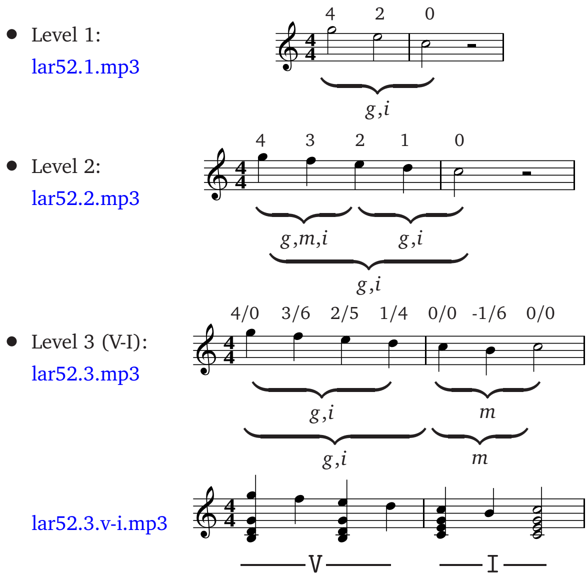

Figure 9: Larson's example (5.2) Larson 1997a with embellishments, forces and harmony

This section serves to explain how the forces shown as in the figure are to be specified, how they 'control' the transitions between levels, and how perceived harmony affects this. The example is initially built from the *C Ionic Major* triad notes. At the second level, the melody is filled in with intermediary notes to make it descend stepwise, and at the final level, it does what Larson calls a 'crouching recovery' (Larson

1997b, 103), i.e. it dips below the tonic and then returns.

As can be seen, the additions to the melody are increasingly less stable (viz. Definition 3.1.8). The bottom shows the example harmonised according to a `V-I` cadence, while the staff above it indicates the effects on the note degrees – i.e. what roles they take on – in case the melody is perceived like this. It also assigns forces at the ensuing relative points of stability. These will now be defined, as well as how they direct the transitions from level to level. After that, it is specified how the musical events as given by the forces and the harmony are mapped to physical ('world') events, which comprises the semantics.

Partitions and events As Figure 9 shows, forces are assigned to groups of notes where stable points occur, which implies that these are partition boundaries within note sequences. As can be seen, such groupings may be separate or they may share a boundary. While conceivably, some possible underlying harmonic motions might be derived from a melodic line (e.g. the example starting on the dominant suggests mode `V`), it is assumed here that such motions are given, or rather that there is a role substitution sequence (viz. Definition 3.1.7) on the basis of one. Hence to partition a note sequence, all that is needed is the substitution sequence.

Definition 3.2.1. *Given a role substitution sequence R for a note sequence N, a partitioning P is a list of sublists called partitions, such that preferably for the first, but certainly for the last item n/s of each, $s \in \{0, 2, 4\}$, i.e. s is one of the stable triad tones. Moreover, intermediary notes should be less stable than these boundaries. P may be split into P_v and P_s so as to separate the partitions into one for note positions (values) and one for role substitutions.*

The above prefers partitions according to Larson's aforementioned 'simple motion' without requiring them. Some subsequent partitions have two notes, and may start on an unstable one (an example was already given earlier in Figure 3).

Recall Schlenker's definition (1.1.1 here) of a possible denotation, which assumes a musical line, or voice, is divided into musical events. The above definition serves to specify how this might be done. In Figure 9 there are two such events, while there are also overlaps which underscore that there may be more than one way to partition a line (i.e. the above definition is non-deterministic). How forces are assigned and work across levels is clarified next.

Forces and partitions Larson's forces of gravity, magnetism and inertia are assigned to partitions of the musical line, and depend on information about stability and direction. The relevant definitions below apply to some partition p in a partitioning P, where p may be given as p_v or p_s, as in Definition 3.2.1. The idea for gravity is that it applies to a partition where musical motion is towards a stable threshold (or 'platform', viz. Larson & VanHandel 2005, 122). It may then be specified as follows.

Definition 3.2.2. *Let p_v be a partition of length ≤ 2, with x, y and z their first, penultimate and last elements (so x and y may coincide). Then p_v is gravitational (marked g) in case $y > z$, and if $x \neq y$ then also $x > z$.*

This definition is meant to be consistent with table 5 in Larson & VanHandel 2005, 122, tentatively generalising to note patterns larger as well as smaller, than the listed three-note ones – which include patterns that start and end on the same note, hence the second condition. Considering Figure 9 the situations are more straightforward in that in all cases, it suffices to note that the partitions marked g are all descending, i.e. $x > y > z$.

As for magnetism, it was mentioned earlier (in Section 1.2) that while Larson has in the past regarded it as a measure of attraction to a more stable pitch analogous with physics, he has later come to define the concept in a binary fashion: as the question whether or not a note resolves via semitone resolution – because particular statistical regression experiments gave 'better results' (as indicated in Larson 2002, 381 fn.6). However, the core idea, like physical magnetism, is as follows: the closer a note gets to its goal, the stronger magnetic attraction becomes. It is one way to characterise goal directedness in music, and hence the concept is specified and applied in general here, using Larson's physics measure in terms of semitone distances.

The idea behind Larson's (general) magnetism definition (Larson 2004, 463), then, is to gauge the attraction ('pull') from some unstable note to its resolution. This is measured in terms of where it actually goes, called the attractor, and where it might have gone if it had moved the other way, which is termed the opponent ('opposing attractor' in Larson 2004). These notions are made precise below.

Definition 3.2.3. *Given a partition p_v, a scale S, its instantiation I and a mode m, the relative stabilities q are $([0,2,4]+m)$ mod 7. Let t and u be the penultimate and last elements of p_v, and set $t_s = t$ mod 7 and $u_s = u$ mod 7 (i.e. their respective note values are $I[t_s]$ and $I[u_s]$). Then for each element i in q determine candidate semitone distances x_i and y_i as follows: $x_i = (t_s - S[q_i])$ mod 12, and $y_i = 12 - x_i$. Now put each $min(x_i, y_i)$ in D, and then the attractors A are note value/distance pairs v/d with each n given by $I[q_i]$, and d by its associated d in D. With the partition's last note and distance $I[u_s]/d_u \in A$, this will be called the partition's attractor a_p. If this element is discarded from A, the remaining element with the smallest d is its opponent o_p.*

The above definition entails that each partition has attractors and opponents, and consequently each has a magnetism value. Once the attractor and opponent are known, this value is computed as follows.

Definition 3.2.4. *Given some partition p_i, its attractor $a_i = v_i/a_i$ and opponent $o_i = w_i/o_i$, the magnetic value of p_i is given as $m_{p_i} = \frac{1}{a_i^2} - \frac{1}{o_i^2}$. Given its penultimate note value v_p, the partition is binary magnetic (marked $\overline{m}$) if $abs(v_i - v_p) = 1$. If $v_i - v_p < 0$ then p_i is downward magnetic ($m_\downarrow$), and else upward magnetic ($m_\uparrow$). In the latter case, if p_i resolves to the tonic and is binary magnetic, it has crouching recovery ($m^\star$).*

The last binary magnetism part refers to semitone resolution (see Section 1.2). To illustrate the more general numeric case, magnetic values will be computed for the two upper partitions in level 3 of Figure 9 (although only the latter has been marked as such since it is binary).

The first partition $p_1 = [4,3,2,1]$, while the scale $S = [0,2,4,5,7,9,11]$, its instantiation $I = [c,d,e,f,g,a,b]$, and its mode $m = 4$, i.e. even though the partition is in mixolydian mode (V), the scale perspective is nonetheless *C Ionic Major* (this may incidentally also be called the *key*). The relative stabilities are $q = ([0,2,4]+4)$ *mod* $7 = [4,6,1]$, and $t = t_s = 2$ and $u = u_s = 1$. These are respectively $I[2]$ and $I[1]$ i.e.

e and d. Now $x_0 = (I[2] - I[q_0])\ mod\ 12 = (I[2] - I[4])\ mod\ 12 = (4 - 7)\ mod\ 12 = 9$ and $y_0 = 12 - 9 = 3$. Then similarly $x_1 = (4 - I[6])\ mod\ 12 = (4 - 11)\ mod\ 12 = 5$ and $y_1 = 12 - 5 = 7$, and $x_2 = (4 - I[1])\ mod\ 12 = (4 - 2)\ mod\ 12 = 2$ and $y_2 = 12 - 2 = 10$. Then the smallest distances to the attractors $D = [3, 5, 2]$ and so the attractors $A = [g/3, b/5, d/2]$. The attractor is the last note d, and removing this leaves $g/3$ with the smallest distance, hence g is the opponent.

As for the second partition $p_2 = [0, -1, 0]$, the scale and instantiation are as above, but now the mode $m = 0$, so $q = [0, 2, 4]$. The penultimate $t = -1$ and $t_s = -1\ mod\ 7 = 6$, while for the last note $u = u_s = 0$. Their values are $I[6]$ and $I[0]$, i.e. b and c. Now $x_0 = (I[6] - I[q_0])\ mod\ 12 = (11 - 0)\ mod\ 12 = 11$ and $y_0 = 12 - 11 = 1$, $x_1 = (11 - 4)\ mod\ 12 = 7$ and $y_1 = 5$, and $x_2 = (11 - 7)\ mod\ 12 = 4$ and $y_2 = 8$. So $D = [1, 5, 8]$ and $A = [c/1, e/5, g/4]$. The attractor being $c/1$, discarding this in A leaves opponent $g/4$.

So for p_1 the attractor $a_{p_1} = d/2$ and the opponent $o_{p_1} = g/3$, while for p_2, $a_{p_2} = c/1$ and $o_{p_2} = g/4$. Then $m_{p_1} = \frac{1}{a_1^2} - \frac{1}{o_1^2} = \frac{1}{4} - \frac{1}{9} = \frac{5}{36} \approx 0.14$. As for p_2, the attractor $a_{p_2} = c/1$ and the opponent $o_{p_2} = g/4$, and so $m_{p_2} = \frac{1}{a_2^2} - \frac{1}{o_2^2} = 1 - \frac{1}{16} = \frac{15}{16} \approx 0.94$. This demonstrates that while indeed magnetism values may be computed for any partition, they tend to be (considerably) higher for partitions that resolve by a semitone (as mentioned in the paragraphs preceding Definition 3.2.3).

Finally, inertia. This broadly speaking means to continue in the same manner, which may be a direction or more generally a pattern. The latter being too broad for convenience, only upward, downward, still, and alternating are specified.

Definition 3.2.5. *A partition P_v is inertic if it is still, moves continuously upward or downward, or is alternating. In the first case (marked i), its length > 1 and for all $x_1, \ldots, x_n \in P_v$, $x_1 = \ldots = x_n$. In the next two cases ($\mathrm{i}_\uparrow$ and $\mathrm{i}_\downarrow$), P_v has length > 2 and for all $x_1, \ldots, x_n \in P_v$, either $x_1 < \ldots < x_n$ or $x_1 > \ldots > x_n$. In the final case ($\mathrm{i}_\updownarrow$), the length of $P_v \geq 3$ and for each consecutive pair $(x, y), (y, z) \in P_v$, either $x < y > z$ or $x > y < z$.*

In Figure 9, just the downward cases appear but the others can presumably be imagined. In the next section, the focus is on the relationship between the forces and transitions between musical levels.

Forces and transitions As already highlighted, according to Larson, musical pieces are to be viewed as constructed level by level, with higher levels figuring as embellishments of the lower ones, and transitions from lower to higher controlled by the forces (Larson 2004, 457). Transitions are specified non-deterministically, i.e. there may be multiple solutions.

Definition 3.2.6. *Given a partition P_s and its accompanying harmonic sequence H, consider the partition P_s' and its sequence H'. P_s' is an embellishment of P_s in case the following conditions hold: (1) length$(P_s') >$ length(P_s); (2) there is at least one $s \in P_s$ such that s is less stable than any $s \in P_s'$ (i.e. P_s and P_s' are constructed respectively from an embellishing alphabet pair); (3) no $h \in H'$ is more stable than any $h \in H$. If these conditions hold, then (P, P') is a transition. A sequence $T = [P_1, \ldots, P_n]$ is transitional if each pair $(P_i, P_{i+1}) \in T$ is a transition, in which case each $P \in T$ is a level.*

Even if the above does not say how one note embellishes another note, how embellishments are 'controlled by the forces' can now be specified if left-branching is assumed following Lerdahl & Jackendoff 1983, 181, meaning the most significant note is at a partition's end and that musical motion is towards this.

Definition 3.2.7. *Given a force F, a transitional sequence T and a transition $t = (P_i, P_{i+1}) \in T$, t is controlled by F if P_{i+1} is F, and strongly controlled by F if P_{i+1} is F but not P_i.*

Note particularly that magnetism is in this case to be considered as semitone resolution, i.e. binary like the other forces, instead of following Definition 3.2.4 which assigns it numerically to any partition (viz. Section 1.2). Other than this, note how in Figure 9, gravity controls how the notes are filled in between levels 1 and 2. The next section is to connect Larson's forces to Schlenker's semantics.

3.3. Musical meaning

The goal of this section is to associate musical forces with situations and events in the world, following what was set out about Schlenker in Sections 1.1 and 2, particularly concerning the idea of a 'bona fide' semantics, which is a relation between music and a reality external to the music itself. In that sense, Larson's forces could be viewed as an 'internal semantics' (viz. Schlenker 2019, 41).

Musical example To begin with, the example depicted in Figure 9 will be extended and given such a semantics, to be followed by some more examples later. The extension (level 4) is shown in Figure 10 below, with postfix markings as specified in the previous section. So Figures 9 and 10 together constitute four levels.

- Level 4 (V-I-V-I):
  lar52.4.mp3

  lar52.4.v-i-v-i.mp3

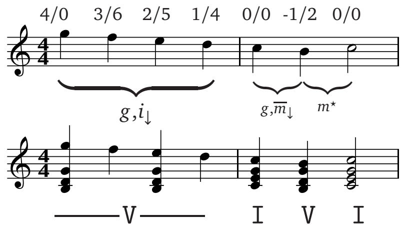

Figure 10: Additional level for Larson's ex. (5.2) Larson 1997a with forces and harmony

The partitions may be viewed as musical events, written as (sequences of) quadruples $\langle harmony, gravity, magnetism, inertia\rangle$ as in Equation 3.3.1, which gives the events for all four levels $L_1 \dots L_4$ – see the next paragraph, Definition 3.3.2, for the format.

Equation 3.3.1.

$$M_{L_1} = \langle\langle \mathtt{I}, 1, -0.05_{\downarrow}, 1_{\downarrow}\rangle\rangle$$
$$M_{L_2} = \langle\langle \mathtt{I}, 1, \overline{0.75}_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{I}, \varnothing, 0_{\downarrow}, \varnothing\rangle\rangle$$
$$M_{L_3} = \langle\langle \mathtt{V}, 1, 0.14_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{I}, \varnothing, 0.94^{\star}, \varnothing\rangle\rangle$$
$$M_{L_4} = \langle\langle \mathtt{V}, 1, 0.14_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{V}, 1, \overline{0.89}_{\downarrow}, \varnothing\rangle, \langle \mathtt{I}, \varnothing, 0.94^{\star}, \varnothing\rangle\rangle$$

The magnetism values for M_{L_3} and the outer ones for M_{L_4} are as in the example computation after Definition 3.2.4. M_{L_4}'s middle partition (following Definition 3.2.3) resolves to b from c by 1 semitone with its opponent at d and 3 semitones. For M_{L_1} note that the attractor is c with a distance of 4 semitones (from the predecessor b), and the opponent is g with a distance of 3. For M_{L_2}'s first partition, the attractor is e which has distance 1, with opponent g that has distance 3.

Voice and truth Next, musical events M are to be mapped to world events W. The idea is to arrive at a denotation *bird-landing* by mapping *harmony* to altitude, *gravity* to wind pressure, *inertia* to wing power, and *magnetism* to gravitional force. The latter may seem odd or confusing, but the mapping only needs to preserve structure and need not correspond to musical features (as Schlenker puts it, a virtual source does not have to be sound-producing – Schlenker 2019, 38). First however, the truth definition will be given by adapting Definition 1.1.2 from Section 1.1, preceded by the specification of a voice (i.e. Equation 3.3.1 contains voices).

Definition 3.3.2. *A voice is a sequence of musical events rendered as quadruples with values for harmony, gravity, magnetism and inertia. Harmony values are written in Roman numeral notation while gravity is 1 if true. Magnetism is given in terms of attraction value (viz. Definition 3.2.4), marked with suffixes ($v_\downarrow$ if downward, $v_\uparrow$ if upward, and $v^\star$ if crouching recovery), or overline ($\overline{v}$ if binary magnetic). Inertia is similary marked for downward or upward, or for alternating ($v_\updownarrow$). Absence of one of Larson's forces is indicated by ø (as magnetism may be 0).*

So according to the above, M_{L_4} in Equation 3.3.1 is a voice, and the next definition serves to enable mappings $M \longrightarrow W$, i.e. turn musical events into 'world' events.

Definition 3.3.3. *Let $M = \langle M_1, \ldots, M_n \rangle$ be a voice, and $\langle O, \langle e_1, \ldots, e_n \rangle\rangle$ a possible denotation for M (see Definition 1.1.1). 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) Forces: If M contains the following forces then these act to move O to a position of – relative – stability.

(1) If M is gravitational, then O moves, under the influence of gravity or a similar constant force, to a stable position of less energy, i.e. e_n has less energy than e_1 (this and subsequent clauses assume Schlenker's ideas on pitch inferences, (Schlenker 2019, 52-53), where higher pitch or frequency

is associated with more events, i.e. more energy or energy potential).

(2) *Since all M are magnetic, O is assumed to be attracted to a stable position to some degree, with values interpreted as 'closeness to a goal'. If M is downward magnetic, O will be in a position of less energy (e_n has less energy than e_1), and if M is upward magnetic, it will be in a position with more energy – unless e_n resolves to tonic position, in which case energy is assumed to be absorbed ('crouching recovery').*

(3) *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, and if M is upward inertic, O follows a steady pattern to a position with higher energy. If M is still inertic then O remains in the same position. Finally, if M is alternating inertic then O follows a regular but alternating pattern, which is to a less energetic position if M is also gravitational, or to a position with more energy 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.*

Mapping to denotation On the above definition, the following denotation is true of M_{L_4}, as a mapping $M_{L_4} \longrightarrow W_{L_4}$. This mapping is stipulated as being *harmony* $\longrightarrow$ *altitude*, *gravity* $\longrightarrow$ *wind pressure*, *magnetism* $\longrightarrow$ *gravitational force* and *inertia* $\longrightarrow$ *wing power*, with these terms abbreviated somewhat in Equation 3.3.4 below (where the idea is that W_{L_4} = *bird-landing*).

Equation 3.3.4.

$$W_{L_4} = \left\langle bird, \left\langle \begin{matrix} altitude{=}high, \\ wind{=}high, \\ force{=}low, \\ power{=}high \end{matrix} \right\rangle, \left\langle \begin{matrix} altitude{=}high, \\ wind{=}low, \\ force{=}medium, \\ power{=}low \end{matrix} \right\rangle, \left\langle \begin{matrix} altitude{=}low, \\ wind{=}low, \\ force{=}high, \\ power{=}low \end{matrix} \right\rangle \right\rangle$$

This equation is a mapping similar to the one Schlenker makes from his equation (23) in Schlenker 2019 on p. 66 (M =

$\langle\langle \mathtt{I}, 70db\rangle, \langle \mathtt{V}, 75db\rangle, \langle \mathtt{I}, 80db\rangle\rangle$ to (26_a) on page 68 (*Sun-rise* = $\langle$*sun*, $\langle$*minimal-luminosity*, *rising-luminosity*, *maximal-luminosity*$\rangle\rangle$), except here, the denotation consists of attribute/value pairs. Moreover, rather than tacitly mapping combinations of musical events to single events (e.g. Schlenker maps I and $70db$ to *minimal-luminosity*), mappings of individual musical events have been made explicit, hence there are multiple sub events in the above equation.

The example shows two particular instances of changing energy levels where one decreases while the other increases. The former is altitude as mediated by *harmony*, which decreases because height implies energy potential of an object. The latter is gravitational force, mediated by *magnetism*, which increases as the object approaches the earth, with attraction maximal on the ground.

Additional features that have been brought into the equation are wind pressure (*gravity*) and wing power (*inertia*). The former is absent in the last partition and the latter in the final two, meaning their last values have been copied into the subsequent partition(s). In both cases this follows energy considerations from Definition 3.3.3 (b_1 and b_3, respectively). Of further interest are the altitude and gravitational force features, particularly the latter, since the increasingly stronger magnetism (in Equation 3.3.1's M_{L_4}) implies increasing closeness to a goal – where the final magnetic force is a 'crouching recovery' with the landing absorbing (kinetic) energy. As for the prior levels, note that levels 1 and 2 might be interpreted as *bird-moving*, which can be considered as a partial interpretation, where it also conveniently holds that *bird-landing* $\models$ *bird-moving*.

Even though not all forces were assigned in all partitions of Figure 10, their mapped images are all in Equation 3.3.4. To underpin this, three final concepts should be specified: event map, energy update and eventful denotation (i.e. Equation 3.3.1).

Definition 3.3.5. *An event map is a pair* $\langle \mathscr{M}, \mathscr{W}\rangle$ *where* $\mathscr{M}$ *is a list of mappings* $\mathscr{F}$ *from musical features to features in the world* $\mathscr{G}$*, and* $\mathscr{W}$ *is a list of partial orderings for the values of* $\mathscr{G}$*, ordered from higher to lower levels of energy, with potential incomparable values written as* v°.

So with $\mathscr{M}$ for the mapping in Equation 3.3.1 being given above it, $\mathscr{W} = [\{high, low\}, \{high, low\}, \{high, medium, low\}, \{high, low\}]$.

Definition 3.3.6. *Given an event map* $\langle \mathscr{M}, \mathscr{W} \rangle$*, a force* f *and an attribute/value pair* $a = v$ *(with* $a \in \mathscr{M}$ *and* $v \in \mathscr{W}$*), an energy update gives a new value* v' *for* a *(i.e.* $a = v'$*) picked from* $\mathscr{W}$ *under the following rules:*

(1) If f *is downward or gravitational, then if available,* v *is the next comparable value smaller than* v.
(2) If f *is upward, if available,* v *is the next comparable value greater than* v.
(3) If neither of the above is the case or if no such comparable value, then $v' = v$.

It can now be specified how to exhaustively map musical events into a denotation, thereby completing the semantics.

Definition 3.3.7. *Given a voice* M*, a denotation* $\langle O, E \rangle$ *is eventful in case* $M \longrightarrow E$ *is an injective homomorphism (i.e. every* $m \in M$ *is covered by some distinct* $e \in E$*), which holds in case the following does:*

(1) If a force is absent in a partition but present in its predecessor partition, the predecessor value is used after an energy update. For successors the value is subsequently constant. If it is present in the successor the energy update is in reverse, with further predecessors having constant values.
(2) If a force is absent in a partitioning but present in the encompassing partition, its value is applied to the last sub partition, and to their predecessors with reverse energy update.
(3) If a force is absent in an encompassing partition but present in a sub partition, the encompassing partition receives the value of the last sub partition.

By way of illustration how this applies, consider the second measure in Figure 10, which consists of two partitions where inertia has not been assigned (though it strictly could have been in case the last three notes had been viewed as a single partition). Given *inertia* $\longrightarrow$ *wing power* $\in \mathscr{M}$ and $\{high, low\} \in \mathscr{W}$, the last two values in Equation 3.3.4 follow from Definition 3.3.7's first clause. Encompassing partitions will crop up in the final two examples.

Minimal pairs As mentioned in Section 1.1, Schlenker's methodology includes the construction of so-called minimal pairs, where a change is applied to an instance to make the conjectured meaning disappear (Schlenker 2019, 62). For the example of Figure 10, such a change is depicted in Figure 11 below, and rendered in Equation 3.3.8, so that the minimal pair is (M_{L_4}, M'_{L_4}).

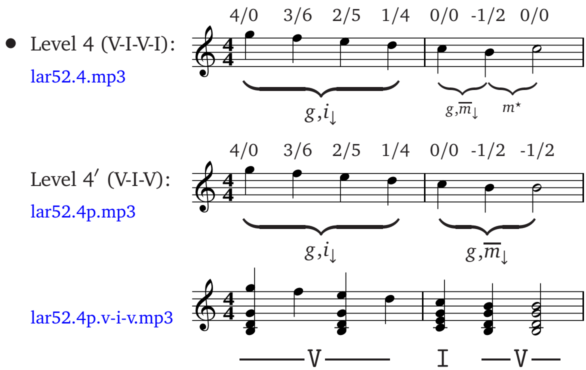

Figure 11: 'Minimal pair' change to Larson's example (5.2) (Larson 1997a)

Equation 3.3.8.

$$M_{L_4} = \langle\langle \mathtt{V}, 1, 0.14_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{V}, 1, \overline{0.89}_{\downarrow}, \varnothing\rangle, \langle \mathtt{I}, \varnothing, 0.94^{\star}, \varnothing\rangle\rangle$$

$$M'_{L_4} = \langle\langle \mathtt{V}, 1, 0.14_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{V}, 1, \overline{0.89}_{\downarrow}, \varnothing\rangle\rangle$$

The minimal change involves repeating the penultimate note. The idea is that since the music no longer resolves (to the tonic), the altitude does not reach the level 'low', and therefore the bird does not land – hence the denotation W_{L_4} is no longer valid.

This section will be concluded with two further examples, which will omit the minimal pairs as shown above. The first of these shows a melody in major and minor in order to demonstrate the effect of different scales on a note sequence, while the second example is not stepwise.

Major and minor example This example, like the previous one, is from example (5) in Larson 1997a; this time it is the eleventh pattern which is the non-resolving $[0, -1, 0, 1, 2, 3, 4]$ (0-based here unlike in the paper, and in fact the reverse of the preceding example). It is depicted in Figure 12 below, in *C Ionic Major*, *C Aeolian Minor* and *C Harmonic Minor*, and harmonised using first, sixth and fifth modes. Some brackets where no immediate force could be assigned are left blank.

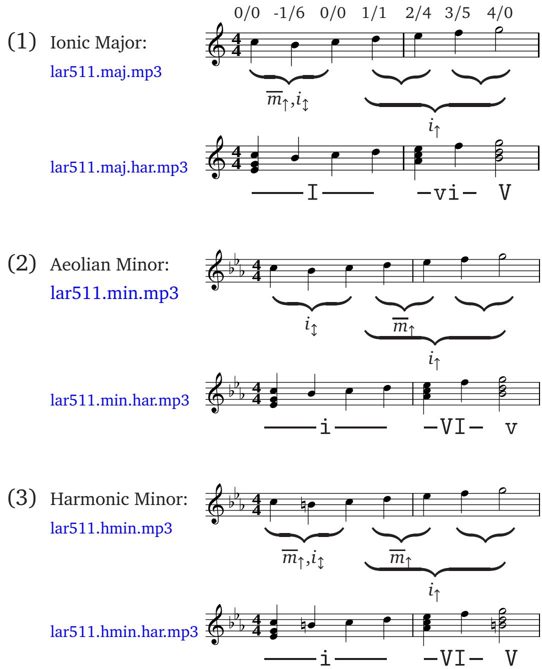

Figure 12: Larson's example (5.11) (Larson 1997a) in three different scales

In the harmonised parts of the figure, the convention is used to write chords with major aspect in uppercase Roman numerals, and the minor ones in lowercase (where first mode `i` should not be confused with inertia i), to highlight how the choice of scale affects this. The more specific point is to demonstrate how this affects distances in a note sequence, and ultimately the assignment of forces and semantics. The scale and harmony effects are made explicit below for the harmonic minor case, after which musical and world events are given.

The scale measurement for harmonic minor is $[0, 2, 3, 5, 7, 8, 11]$ (Definition 3.1.2). With pitch collection $[c, d\flat, d, e\flat, e, f, g\flat, g, a\flat, a, b\flat,$

$b]$ (enharmonic, viz. Definition 3.1.1), this instantiates *C Harmonic Minor* as $S = [c, d, e\flat, f, g, a\flat, b]$ according to Definition 3.1.3. Given the progression `i-VI-V`, this implies the following sequence of triads: $[[0, 2, 4], [5, 0, 2], [4, 6, 1]]$ (Definition 3.1.6). These index values are then picked from S to yield $[[c, e\flat, g], [a\flat, c, e\flat], [g, b, d]]$, where the first has minor, and the other two have major aspect (see Definition 3.1.5). The triads at the bottom of Figure 12 are $[[e\flat, g, c], [a\flat, c, e\flat], [b, d, g]]$, as the outer ones have been rendered as first inversions while the middle triad is left in root position.

Equation 3.3.9 shows the musical events for the *Harmonic Minor* case in Figure 12. It is a (hierarchically) structured event because the upward inertic force runs across the last four notes that are in turn subdivided into groups of two. The events are triples $\langle harmony, magnetism, inertia \rangle$.

Equation 3.3.9.

$$M_{L_3} = \left\langle \langle \mathtt{i}, \overline{0.94}_{\uparrow}, 1_{\updownarrow} \rangle, \left\langle \begin{array}{c} \langle \mathtt{V}, 0, 1_{\uparrow} \rangle, \\ \hline \langle \langle \mathtt{VI}, 0.75_{\uparrow}, \varnothing \rangle, \langle \mathtt{V}, 0, \varnothing \rangle \rangle \end{array} \right\rangle \right\rangle$$

The mapping is similar to that of the previous example with $\mathscr{M} = [harmony \longrightarrow altitude,\ magnetism \longrightarrow gravitational\ force, inertia \longrightarrow wind]$, with values $\mathscr{W} = [\{high, medium, low\}, \{strong, medium, weak\}, \{swirles^{\circ}, strong, weak\}]$.

Equation 3.3.10.

$$W_{L_3} = \left\langle leaf, \left\langle \begin{array}{c} altitude{=}low, force{=}strong, \\ wind{=}swirles \end{array} \right\rangle, \left\langle \begin{array}{c} \left\langle \begin{array}{c} altitude{=}high, force{=}weak, \\ wind{=}strong \end{array} \right\rangle, \\ \left\langle \begin{array}{c} \left\langle \begin{array}{c} altitude{=}medium, force{=}medium \\ wind{=}weak \end{array} \right\rangle, \\ \left\langle \begin{array}{c} altitude{=}high, force{=}weak \\ wind{=}strong \end{array} \right\rangle \end{array} \right\rangle \end{array} \right\rangle \right\rangle$$

The proposed denotation is $W_{L_3} = leaf\text{-}floating$. More elaborately put, the idea is that of a leaf floating upwards in the wind, where the decreasing magnetic values mean that the gravitational force gets increasingly less grip on it. With regard to the definitions following the previous example (notably Definitions 3.3.6 and 3.3.7), note that the value *swirles* in $\mathscr{G}$ is not comparable, and also that the second and third note groups in Figure 12, (3) are encompassed by upward inertia, allowing them to be assigned respectively weak and strong wind.

As for the other scales, in *Aeolian Minor* the magnetic value for the partition consisting of the first three notes is 0.14 while in *Harmonic*

Minor it is 0.94. In both cases, the other values are 0.75 and 0, so in *Aeolian Minor* the *wind* pattern [*strong*, *medium*, *weak*] does not obtain; it would instead be [*weak*, *medium*, *weak*], i.e. a different semantics would ensue. This might explain why the motion appears somewhat more graceful in *Harmonic Minor* – which incidentally borrows its half-step leading tone (and hence the binary magnetism) from *Ionic Major*.

Leapwise example The final example is taken from Larson 2004, table 14, pattern 14, with note sequence [4, 2, 3, 1, 2, 1, 0]. As can be seen from the first four notes [4, 2, 3, 1], the example is not stepwise (it has leaps or intervals larger than a whole tone), but there are nonetheless stepwise connections between the notes. To make these explicit, consider Figure 13 below, in particular level 2 which is stepwise, and the complete sequence in level 4.

- Level 1:
  lar14.1.mp3
  (*C* Major triad)
- Level 2 (I-V-I):
  lar14.2.mp3
  (gravitational descent)
- Level 3 (I-V-I):
  lar14.3.mp3
  (inertic note shift)
- Level 4 (I-V-I):
  lar14.4.mp3
  (gravitational descent)

lar14.4.i-v-i.mp3

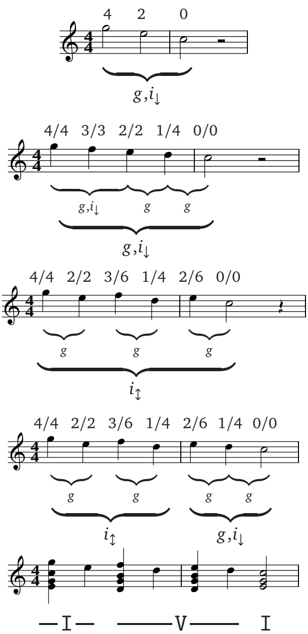

Figure 13: Larson's example (14) (Larson 2004) with embellishments, forces and harmony

The idea is that the stepwise second level arises from the basic first one (the major triad) by a transforming function that adds less stable notes, in this case completing the descent to the tonic – i.e. the transformation is 'controlled by' gravitational descent. At the third level, the mediant is shifted back into second position to create an inertic repeating pattern of notes separated by an interval of a third (a 'leap', whereby the sequence becomes leapwise). Finally, gravitational descent is applied once more to the last measure, yielding Larson's example in full.[11]

Musical and world events will now be given for the second and fourth levels, in Equations 3.3.11 and 3.3.12 respectively. These should be viewed as two levels of perception or perspectives on the same situation. The first one consists of (structured) quadruples $\langle harmony, gravity, magnetism, inertia\rangle$.

Equation 3.3.11.

$$M_{L_2} = \left\langle \left\langle \begin{array}{c} \langle \mathtt{I}, 1, 0_{\downarrow}, 1_{\downarrow}\rangle, \\ \langle\langle \langle \mathtt{I}, 1, 0.75_{\downarrow}, 1_{\downarrow}\rangle, \langle \mathtt{V}, 1, 0.89_{\downarrow}, 1_{\downarrow}\rangle \langle \mathtt{I}, 1, 0_{\downarrow}, 1_{\downarrow}\rangle\rangle \end{array} \right\rangle \right\rangle$$

$$M_{L_4} = \left\langle \left\langle \begin{array}{c} \langle \mathtt{V}, \varnothing, -0.14_{\downarrow}, 1_{\updownarrow}\rangle, \\ \langle\langle \langle \mathtt{I}, 1, 0.07_{\downarrow}, \varnothing\rangle, \langle \mathtt{V}, 1, -0.14_{\downarrow}, \varnothing\rangle\rangle \end{array} \right\rangle, \left\langle \begin{array}{c} \langle \mathtt{I}, 1, 0_{\downarrow}, 1_{\downarrow}\rangle, \\ \langle\langle \langle \mathtt{V}, 1, 0.14_{\downarrow}, \varnothing\rangle, \langle \mathtt{I}, 1, 0_{\downarrow}, \varnothing\rangle\rangle \end{array} \right\rangle \right\rangle$$

Like in the previous example, the events are structured in order to reflect the larger as well as the smaller partitions of the note sequence(s). The event map $\langle \mathscr{M}, \mathscr{W}\rangle = \langle [harmony \longrightarrow lean, gravity \longrightarrow speed, magnetism \longrightarrow tide, inertia \longrightarrow wind], [\{false, true\}, \{high, medium, low, none\}, \{strong, medium, still\}, \{strong, weak, swirles^{\circ}\}]\rangle$. The intended denotation is *sailboat-arriving*.[12]

Equation 3.3.12.

$$W_{L_2} = \left\langle sailboat, \left\langle \left\langle \begin{array}{c} \langle lean{=}false, speed{=}none, tide{=}still, wind{=}still\rangle, \\ \langle lean{=}false, speed{=}high, tide{=}medium, wind{=}strong\rangle, \\ \langle lean{=}true, speed{=}low, tide{=}strong, wind{=}weak\rangle, \\ \langle lean{=}false, speed{=}none, tide{=}still, wind{=}still\rangle \end{array} \right\rangle \right\rangle \right\rangle$$

$$W_{L_4} = \left\langle sailboat, \begin{array}{c} \left\langle \begin{array}{c} \langle lean{=}true, speed{=}medium, tide{=}still, wind{=}swirles\rangle, \\ \left\langle \begin{array}{c} \langle lean{=}false, speed{=}high, tide{=}still, wind{=}swirles\rangle, \\ \langle lean{=}true, speed{=}medium, tide{=}still, wind{=}swirles\rangle \end{array} \right\rangle \end{array} \right\rangle, \\ \left\langle \begin{array}{c} \langle lean{=}false, speed{=}none, tide{=}still, wind{=}weak\rangle, \\ \left\langle \begin{array}{c} \langle lean{=}true, speed{=}low, tide{=}still, wind{=}strong\rangle, \\ \langle lean{=}false, speed{=}none, tide{=}still, wind{=}weak\rangle \end{array} \right\rangle \end{array} \right\rangle \end{array} \right\rangle$$

W_{L_2} represents the broad perspective of the boat's movement towards the shore (or harbour, land, etc.), while W_{L_4} zooms in on some more details. For instance, the tidal motion in W_{L_2} is a factor bringing the boat in, because the associated magnetism values are large and increase (and end up zero). In W_{L_4}, magnetism stays around zero due to leap motion and partitioning, which may be interpreted as an observer focusing on the boat and the water around it, which would appear still relative to the vessel. This shows how both perspectives may be used for the complete picture, just as the levels in Figure 13 are, with the second one needed to bring out the 'hidden' stepwise structure of the example's melody.

Things being 'still' in the top part of W_{L_2} in Equation 3.3.12 (the bottom bracket in Figure 13) may seem odd, but this is due to the choice of viewing Larson's forces as applying to the end of an event, so what is being referred to is the boat having arrived. What happens during the event is taken care of by the three sub partitions, where things are (partly) in motion. While for the first example (Figure 9), there is an entailment relation between levels 2 and 4 (*bird-landing* $\models$ *bird-moving*), this is not the case here, since as indicated, the levels are complementary.

4. DISCUSSION

Meaning The general idea underpinning Schlenker's music semantics is that meaning is a relation between the symbols of a language and a language-external reality, and so under the assumption of music being a kind of language, it is required that any semantics establish a relation between a musical piece and some music-external reality (Schlenker 2019, 41). What Schlenker says concerning his *Sun-rise* example (mentioned here in Section 1.1, see also *ibid.*, 68) is that his structure-preserving mapping or truth definition *"can deliver a notion of truth"* before going on to list denotations. The underlying idea for this paper – having been adopted from Schlenker – is the same, but it begs the question: is 'a notion of truth' also 'a good notion of meaning'?

This is perhaps the hardest question of all to answer, but the main point is that it draws on a general view of semantics as truth-conditional. This is the idea behind Schlenker's more general ideas on 'Super Semantics' (viz. Section 2 and Schlenker 2018): studying other representative systems, including music, to see if they can also be given truth conditions. But one of the attractions of a truth-conditional account of meaning in language is that it is reasonable to assume that both speaker and hearer will tend to agree on the conditions under which a statement is true, which forms an important foundation for language as a means of communication: the hearer understands what the speaker says as intended. But it is much less clear if this is also the case here: are the denotations of the musical sequences given here what the composer or musician intends them to mean, and given they mean this or anything for that matter by these, could the hearer be expected to be in agreement with that?

While it seems unlikely that a composer and hearer would agree on denotations as they have been instantiated here and in Schlenker 2019, Schlenker's way out of the conundrum is the claim that the information conveyed by music is more abstract than language does (page 36), and the more abstract the information the more possible denotations – as witnessed by the various denotations highlighted here in Section 1.1 (see also *ibid.*, 68). As the author points out, even a statement like *"It is raining"* can refer to a multitude of possible situations, which boils down to saying that this, too, is in some way abstract in that saying it does not fill in all the details of the situation, however, it does constrain the nature of the possible situations that may be true.

The musical events in Schlenker (such as in *(26)* on page 68) or the attribute/value pairs in the musical event equations here should then be similarly deemed 'abstract' in that they allow several situations in the world to cohere with them, but not any. Larson's forces are to be viewed as constraining the possible ways of 'filling in the details'. So basically from the point of view of communication from composer to hearer, what is being communicated are constraints of physical metaphor, but ultimately this squares with Schlenker's truth-conditional view since as he points out, *"It is raining"* may similarly refer to multiple realities (*ibid.*, 67).

Formalisation At the beginning of Schlenker 2019, Schlenker states his aim: to argue that a formal semantics of music can be developed, yet the paper is mostly informal. It has two formal definitions, namely voice and truth (*(24)* and *(25)* on pages 66-67), plus formal write-ups of some denotations (*(26)* on page 68), but other than that it relies on an informal appeal to intuitions about semantics and music. This is not a problem given the goal of arguing for the possibility of formalisation which is not the same as the act of it. Nevertheless, it is one reason that in the present paper, an attempt has been made to express things formally where they could.

Another motivation is that only (numerical) magnetism was defined precisely by Larson (Larson 2004, 463); in other cases forces were informally specified in the text. But moreover there is the underlying theme in Larson's work that forces act to move music to points of stability, which implies these stabilities can be exploited to partition a musical line into musical (sub) events. Schlenker tacitly acknowledges such partitions, but it is rather arbitrarily left up to the listener or interpreter to decide where or what these are. Hence it was decided here that stabilities decide partitions and therefore events, which should be formally specified.

A third reason is the argument already mentioned at the start of this paper and set out in Hamm, Kamp & van Lambalgen 2006: regardless of whether a semantics is to be viewed as in the realist or the cognitive tradition, it requires formalisation to ensure computability of cognition. It should be noted here that Schlenker's music semantics has features of both traditions. It is realist in its appeal to truth conditions, which constitute the relation between the symbols of the language and aspects of the world, and are considered independent of meanings as grasped by a mind (*ibid.*, 1). But in Schlenker's semantics, these aspects are fictional (Schlenker 2019, 37), and in this sense it would be hard to deny a cognitive dimension to the semantics. Moreover, it is a semantics of events, with events explicitly marked as a category within conceptual structures in cognitive semantics, which are generated algorithmically (Hamm et al. 2006, 2). This holds for the musical and the 'world' events in Schlenker 2019 as well as here.

The final motivation for formalisation is to reduce the reliance on music theory for understanding the semantics. This means a trade-off: it should be easier to process for those with a background in logical semantics, while other works may be less accessible to logicians but more to musicians or music researchers. But in any case a choice had to be made, even if this has implications in terms of audience. Attempts have however been made to describe the aims behind the definitions informally so that one need to be able to follow all the details.

It should be noted that a formal semantics approach as applied here risks diminishing the role of the sort of qualitative introspective intuitions that are central to Schlenker,[13] however, one aim of this paper was to consider Schlenker's claim that a formal semantics of music can be developed, and see what that might look like. If this is at the expense of such intuitions, it is an open question whether that results from the particular formalisations of this paper, or from the effort of formalising as such.

Forces Larson's idea that composing and listening to music is controlled by three forces is interesting in that it only posits three and dubious for the same reason: how can the plethora of music be explained by just three forces? Perhaps it cannot, but the point is he might be praised for his attempt at rather severe reductionism, since each additional force is essentially an extra assumption from the Occam's razor perspective,[14] and if Larson is right about his forces then they are certainly very productive. So while this paper is indebted to Larson for said reductionism since it suggests what may be viewed as a semantic primitives proposal, that is not to say the forces should be accepted 'as is'. See for instance Figure 14:

lar14.2.min.mp3 

Figure 14: Larson's example (14) (level 2) in *A Minor*

The above serves to illustrate what happens to magnetism in case the second level from the example from figure 13 is, instead of in *C Major*, rendered in *A Minor*. The point is that computing magnetism for the last three notes $[c, b, a]$ has attractor a with a distance of 2 (from 'pivot' b), and opponent c has distance 1, in other words, the prediction is stronger attraction to mediant c than to tonic a. This is in part because the stable tones tonic, mediant and dominant are treated equivalently, while it might make more sense to have notes be attracted more strongly to the tonic, e.g. by considering the relative stabilities in Definition 3.1.8.

This issue is to be looked at in more depth in de Neeve (2024) (forthcoming).[15] The same goes for inertia since this is a very general concept; it is after all 'the continuation of a pattern', which may conceivably apply to the development of musical themes, and across key changes (i.e. modulations). Lastly, the truth definition (3.3.3) is highly reliant on the concept of energy due Schlenker's association of it with pitch (Schlenker 2019, 52-53) and because note sequences have been the focus of this paper, meaning the pitch dimension was one of the few ones available. This is fairly restrictive, so the plan is to look at the interaction with some other musical features used by Schlenker (e.g. loudness).

Compositionality As noted in Section 1.2, Schlenker calls his semantics 'source-based rather than compositional' (Schlenker 2019, 39). The only other reference to compositionality is in the appendix (page 97) in the context of so-called internal semantics, i.e. the sort of semantics not considered 'bona fide' (page 41). While this does not boil down to an immediate claim that music semantics is necessarily non-compositional, it does at least suggest the point is not very important. But this is at odds with the idea that compositionality in semantics is a methodological principle rather than an empirical hypothesis (see for instance Groenendijk & Stokhof 1991), which makes the issue hard to ignore or dismiss.

However, Larson's conception of musical levels seems to be able to provide a version of compositionality. If level μ' embellishes level μ such that $\mu' \models \mu$ (as in Figures 9 and 10 for which it was noted that *bird-landing* $\models$ *bird-moving*), then this is compositionality in an intuitive sense: an increase in syntactic informativity is reflected in semantic informativity. This is in an incremental rather than a linear sense, although compositionality could conceivably also be considered linearly by taking events $\langle O, E\rangle = \langle O, \langle e_1, \ldots, e_n\rangle\rangle$ with $\langle O, E\rangle \models \langle O, e_m\rangle$ for any $e_m \in E$. Possibly, this is how thematic development might work, which would imply that incrementality and linearity may sometimes go hand in hand. As noted, this issue will be looked at more closely in the forthcoming thesis, as will compositionality in music semantics as such.

Affect Music semantics has been frequently described in terms of emotional affect, with Meyer's *Emotion and Meaning in Music* (1956) a well-known example. A central idea there is that the mind responds unconsciously to patterns in music completed according to expectation, but is drawn towards them when these are inhibited or delayed, in which case affect or the objectification of meaning may follow (Chapter 4). In particular, delay tends to lead to negative emotions, and subsequent fulfilment to positive ones (strengthened by the delay). Schlenker would however view such aspects of music as part of the pragmatic rather than the semantic dimension, for instance on page 42 of Schlenker 2019 he gives an example of a single-note change at the end of the repetition of Beethoven's famous *Ode to Joy* theme that indeed draws attention to it, but this is considered to be an instance of choosing a particular message or expressing it in a certain way (*ibid.*, 82).

Schlenker is quite explicit that while expecting certain musical content may have emotional effects, this essentially boils down to music conveying information about itself rather than a music-external reality, and hence cannot constitute a 'bona fide' semantics (page 41). But if emotions are themselves external to music, then the question whether a semantics can be based on what emotions a piece of music expresses may not be considered settled on the basis of that argument alone, especially given evidence that music's ability to affect emotion and mood is a chief reason for producing as well as listening to it (see for example Koelsch 2010). Or to push the case further, Schlenker's appeal to truth-conditional semantics is inspired by the informative use of natural language, i.e. on the idea that giving or receiving information is the chief reason for producing as well as listening to language. But then requiring that music also express information about the world may be barking up the wrong tree.

At issue here is what the primary elements of music semantics really are. While Schlenker does not deny the emotional effects of music, he believes that rather than being primary, they are mediated via the musical events to 'world' events mapping, in other words, the world events constitute the primary semantic ontology so to speak, and emotions are a result of this. The basic tenet is the idea of experienced events (Schlenker 2019, 86): the listener recognises or experiences emotions associated with the events a virtual source undergoes as brought out by the mapping from musical events to a denotation.

Schlenker gives a modified truth definition – or rather a first draft – to reflect this idea on page 94, to the effect that if a musical event gets less harmonically stable, then the source gets to be in a less stable emotional state, but he contends that what 'less emotionally stable' would then mean, still has to be unpacked. Moreover, the adapted definition states that the event is what causes the less stable state, and this once again takes the semantics to the Peircian indices perspective by virtue of assuming a causal connection between signal and source (viz. *ibid.*, 74). But the event, i.e. the cause, is imagined, and the music is what plausibly causes the imagination on Schlenker's account, and if this is in turn to cause the emotion then there is arguably rather a bit more to be unpacked to avoid circularity.

5. CONCLUDING REMARKS

This paper has established a way to integrate Steve Larson's musical forces into Philippe Schlenker's music semantics by viewing each force (gravity, magnetism and inertia) as a metaphor for attraction to states of stability in the physical world, such that laws governing energy potential are coherently adhered to. Musical states of stability have been considered as end points of musical events, in order to be homomorphic with physical events via a truth definition. This is an essential extension of Schlenker's semantics, which has no natural way to decide what a musical event is, but it may exploit Larson's theory such that for a given note sequence and harmonic interpretation, a partitioning labeled with musical forces may be obtained – and subsequently, as demonstrated, a denotation.

Since Larson's framework is about pitch and harmony, the approach here has been confined to these features of music, even though Schlenker's semantics involves more properties including loudness. The result is a semantics where an extra-musical reality can be causally associated with a musical expression, as required by Schlenker, which has been made formal in order to ensure computability, but also to allow criticism of the present effort to be made equally precise.

The framework as presented follows Schlenker's approach but is not strictly wedded to it. Particularly emotional affect may turn out to be renderable as extra-musical reality despite Schlenker's insistence that this is essentially 'internal semantics'.

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DISCLAIMER

A revision of this paper was published on November 15, 2024, correcting some typographical errors that occurred in the original version. Additionally, in his (forthcoming) thesis referenced here as de Neeve 2024, the author has addressed some cases where the notion of stability among musical levels in this paper may not fully conform with Larson's intentions, and would hence like to invite readers to consider consulting the thesis.

Notes

[1]Note that in the figure – and elsewhere – a hyperlink is included. If this paper is read in a web browser, it is advised to open the links in a new tab or window so the document stays open.

[2]Schlenker points out that it is also possible for several instruments to play a single voice, or for a single one to play several (Schlenker 2019, 37). In this paper, each example is a single voice.

[3]According to Schlenker, the motion picture's imagery synchronises with a two-stage appearance of a star from behind a planet, with the first five measures corresponding to the first stage, and the latter ones to the second, but only part of this intuition is worked out formally.

[4]If this paper is read in print, go to https://mickdeneeve.github.io/ac/ma/ex/byb.htm for a listing of all mp3 sound file links.

[5]For completeness, a sign is symbolic if its denotation is arbitrary, or conventional.

[6]For further illustration consider a piano keyboard: a whole tone would be where going from one white key to another involves skipping over a black key. The white key areas have two spots without a black key in between. These are precisely the half steps or semitones mentioned.

[7]Pitches as used here are names and do not distinguish between octaves. That the start and end of the sequence are an octave apart is instead read off from the numerical representation.

[8]Traditional names are used here, see Definition 3.1.4.

[9]In major as well as harmonic and melodic minor scales.

[10]$\mathtt{IV} < \mathtt{V} < \mathtt{I}$ and $VI < \mathtt{I}$ imply not only $\mathtt{VI} < \mathtt{IV} < \mathtt{V} < \mathtt{I}$ but also $\mathtt{IV} < \mathtt{VI} < V < I$ and $IV < V < VI < I$, with the first similarly preferred according to Krumhansl 1983. Thanks to an anonymous reviewer for pointing this out due to an inaccuracy in a draft of this paper.

[11]NB. It is not given level by level in Larson 2004.

[12]After Schlenker's *Boat-approaching* mentioned in Section 1.1; see also Schlenker 2019, 68.

[13]Thanks to an anonymous reviewer for pointing this out.

[14]Named after William of Ockham (1287 – 1347), this is the principle sometimes referred to as KISS ('keep it simple, stupid'), which states that in case there is more than one theory competing to explain the same phenomenon, the one that makes the fewest assumptions is to be preferred.

[15]The forthcoming thesis effectively extends the ideas in the present paper, hence the reader may expect significant conceptual and/or textual overlap. Author contact information may be found on the thesis GitHub page.

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