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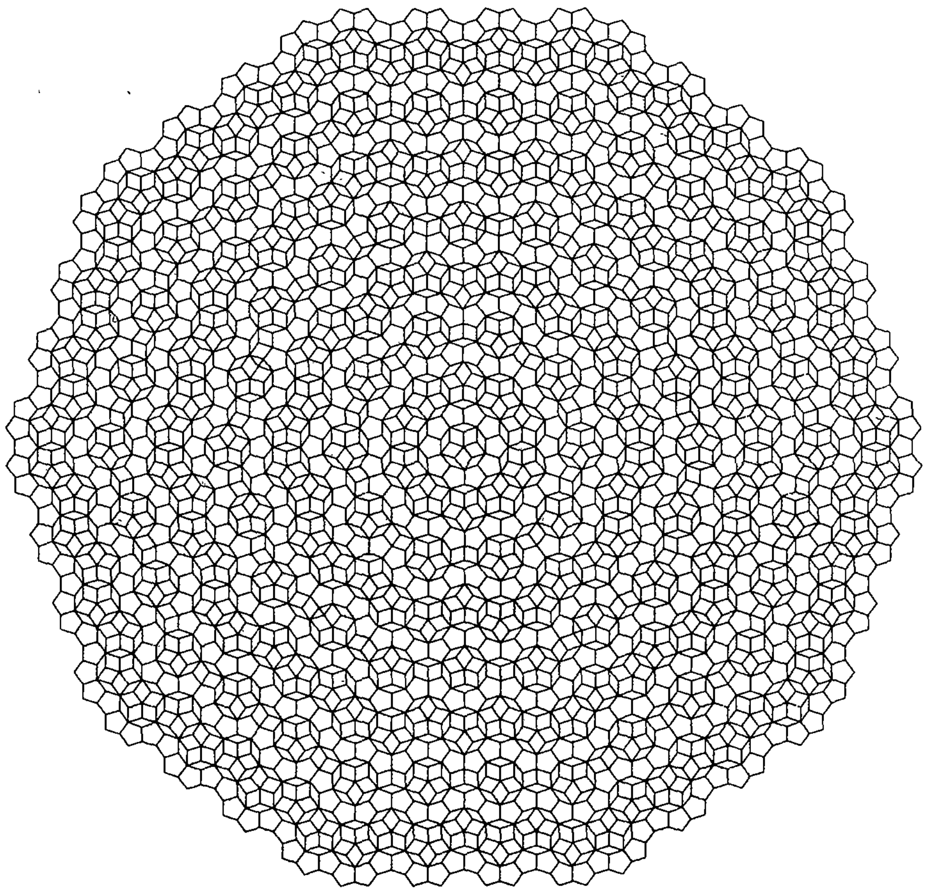

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STRUCTURAL SYMMETRY AND PROPRIOCEPTIVE PATTERNS IN MUSIC

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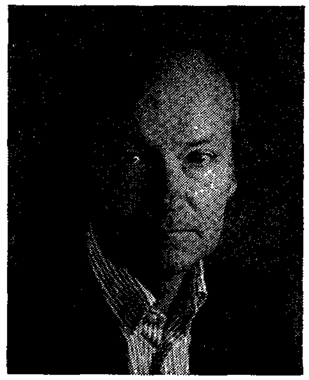

Abstract: *Since music is not just listened to or read from scores, but also performed, there must be symmetries that present themselves only to the musicians. It is argued that such proprioceptive symmetries, and motion patterns in general, form an important aspect of the musical structure as it appears to those who play or sing. It is also a problematical aspect, however. Due to the various constraints of the instruments, patent vehicles for musical symmetries such as the identity of transpositions and the correspondence between rising and falling tonal motions often fail to turn up when the music is performed. And frequently it is not possible to reflect recurrent motifs by means of identical or similar proprioceptive patterns.*

1

That music is the art of sounds is a truth nobody will deny, and yet this commonplace is far from the whole truth. For prior to, or following upon its production in sound music may be recorded by means of symbols on paper. Notation brings the musical process to a standstill and allows the structure to be studied synoptically as you can study a work of visual art. This means that the music is deprived of its driving force and its very medium of existence, i.e. irreversible time. Admittedly, the frozen musical flow can again be heard as sound in motion when the score is read by persons capable of restoring the music in their imagination. Nevertheless, reading remains a peculiar and quite doubtful way to experience and study music.

In addition, though we tend to forget it in our era of massive music consumption via the electronic media, music is composed just as much to be performed as to be heard. Playing or singing music of course includes listening to it, but the core of the experience is that you control the process, and that you feel the music through the sense of touch and especially through the proprioceptive sense, the sense that informs us not about something out there, but about our own joint and muscle movements. Music, then, is not only an art that is heard, it is also an art that is seen and felt.

It seems that the concept of "symmetry" is derived from visual experiences, and that this origin has thoroughly influenced the way we establish and discuss symmetries in music. Though some symmetries do present themselves to the attentive listener, symmetry in music is usually discovered by inspecting scores. But music is an art that evolves in time, and that must have its own laws of symmetry, laws that take account of the fact that musical processes cannot actually be reversed and cannot easily be surveyed.

Unless you read a score, you have to take account of the passages of a composition in the very order prescribed by the composer. Auditive musical symmetries (as opposed to such heard symmetries that emerge when you recall an entire musical work or section, and as opposed to compositional correspondences that emerge only after you have studied the score) are therefore never actually present, but always in the making - they are made up of relationships cumulated in memory and of prospective relation- ships that the stored aspects of the structure give the listener reasons to expect. This means that auditive symmetries tend to be enacted within rather short musical formats. When hearing a comparatively short passage of music, an alert listener is aware of an evolving musical entity displaying both an intricate network of "horizontal" relationships and a complex hierarchic structure. Such phenomenal entities, extending the psychological present by means of the artistic design, may include the necessary vivid resonances of the not too remote past as well as the intuitive glimpses of the near future.

The present paper will be devoted to the proprioceptive patterns and symmetries that are inherent in the motions associated with music performance. These patterns (and proprioceptive sensations associated with playing music in general) are, however private they may seem, very important. As far as music analysis aims at giving a complete account for all aspects of structure and meaning inherent in a work of music, and to the extent that playing music is acknowledged as an activity on a par with listening to it, the experience of a piece of music through the body performing it must be included as a legitimate and integral source of knowledge when it comes to its description - and yet proprioceptive matters have so far been gravely neglected by music analysts. Knowledge of proprioceptive patterns and relationships is indispen-sible if we want to penetrate musical structure, understand musical interpretation, or teach excellence in execution.

The proprioceptive patterns (symmetric or not, coinciding or overlapping with the patterning of the musical structure as the case may be) are of course crucially dependent on the instrument played - the construction and function of the instrument amounts to a set of constraints that condition the playing motions - but also on the transposition (the key) of the music, and on the particular technical manner of execution that for some reason or other is chosen by the musician for the passage in question. That the proprioceptive feeling of musical passages, and hence a crucial element of their essence for the player or singer, may change radically as a result of transposition, is another basic fact, self-evident to all musicians but not duly acknowledged in the musicological discourse - the current, mistaken view is that (apart from small changes in timbre) the music is not affected by transpositions since the frequency ratios between the tones remain the same.

Generally speaking, proprioceptive patterns tend to be intimately related to the technical units, the motion chunks, making up the musician's motor program, and they are presumably also deeply integrated into the cognitive representation of the musical structure as it emerges for the player. Composers (being often accomplished performers themselves or having good insights in performance) are usually keen not only to devise auditive structures that are coherent, orderly, and economic, but they also try to see to it that these musical structures exhibit such qualities from the proprioceptive point of view as well - a truly excellent work of music should also be "idiomatic". And the musicians, using all their wits and imagination, certainly try to bring the playing motions to perfection by arranging the structures to be performed so as to display facilitating regularities and symmetries, and so as to obtain proprio- ceptive patterns that seem to match the structure in a way that serves the musical interpretation - either by supporting an interpretive idea already chosen or by suggesting, giving birth to a new reading of the structural substance.

Most playing motions are intricately and intimately associated with the musical articulation, and some of them, for instance bowing and breathing patterns, are actually the very means for articulation. Others, fundamentally related to the basic act of selecting the prescribed sequence of pitches, more indirectly influence the way the tones are connected: a certain fingering may be compatible with various articulations, but fits best with and might inspire to a particular articulation. The artistic use of articulatory motions is widely acknowledged and makes up a cherished matter much discussed among musicians, while the musical implications of the pitch-selecting motions are more hidden and have been neglected in music analysis; they will therefore be paid special attention in this study.

2

In order to give an idea of the questions involved, the conditions of piano playing will be presented in some detail.

If you hold out your hands with the back of the hands directed upwards, their symmetry is evident: the right hand is mirrored by the left, both thumbs point inwards. But the piano keyboard, as we all know, has a non-symmetric, lateral layout with the bass to the left and the treble to the right. This clash between biologically given symmetry and artificial lateralization causes much of the peculiar character of piano playing. If you want to play the same notated configuration with the left hand as you have just played with the right, you must reverse the finger sequence, and if you let one of your hands exactly imitate the actions of the other, you will hear something inverse and musically quite different. Beyond reflection for proficient players, this paradox is very confusing for beginners and makes both reading and playing difficult, despite the fact that all the notes/keys are neatly displayed before their eyes.

While the two hands are symmetric, the single hand is not. However excellent your pianistic technique is, the fingers are likely to retain something of their original and asymmetrically distributed peculiarities: the slow thumb having its own mode of working, the strong and nimble index and middle fingers, the not entirely indepen- dent and somewhat weaker ring finger, and the little finger which is not only little but sometimes simply too short. And roll down your fingers from the little finger to the thumb, and then from the thumb to the little finger - you cannot but notice the difference in ease, speed and regularity!

Further, whereas our hands look symmetric, they are not alike from the neural point of view. Since most of us have dominant left brain hemispheres, our right hands are generally somewhat more alert, and this difference has in turn influenced the way keyboards are built and the way composers compose for the two hands.

Excepting some genuinely contrapuntal music, the keyboard literature is imprinted by the fact that right and left hand idiomatics are different. High-frequency tones seem apt to move quickly, whereas the greater inertia of low-pitched tones tend to make fast passages sound thick. No wonder then that treble voices generally have much more rapid passage work, and no wonder that the keyboards were devised so as to let the nimble right hand display most of the high-pitched brilliance.

And while the net effect of the technical demands of the repertoire is to increase the constitutional differences between the hands to specialization - the dexterity [!] of the right hand is complemented by the expertise of the left when it comes to wide leaps - methodical practising (and especially playing etudes composed so as to let the left hand do the job of the right, and vice versa) works to level out the natural and induced differences, to give the hands the same technical competence. Human hands skilled at playing the piano, though still made of flesh and blood, are actually artefacts, shaped by the keyboard, by the idiomatic properties of the piano literature, and by years of practice.

As any accomplished pianist can tell, the fingering alternatives are numerous, and (whether planned beforehand or invented instantaneously) fingerings are chosen for their sheer convencience, or since they exhibit an orderly sequence of actions, or because they present a pattern that fits with, indeed metaphorically reflects the structure of the music. But no matter their assets and drawbacks, the fingerings inevitably project their pattern over that of the tonal substance, a fact that determines their artistic usefulness and value. Fingerings have musical meaning, and since they influence the interpretation, they may in principle be heard. The rising C major scale can be played with the current, smooth fingering (right hand: 1-2-3, 1-2-3-4 etc.), but it may also be rendered with two symmetric 1-4 motions that suggest the hidden division of the scale into two identic, disjunct tetrachords, and that subtly bring out the note F as a secondary point of tonal gravity.

Finally, a quick glance at a piano keyboard shows that passages will rarely retain their proprioceptive identity when they are transposed to another "key", i.e., to another set of keys on the keyboard. The irregular distribution of the white and black keys means that the same sequence of intervals, structurally speaking, will have another white/ black "topography" and hence another proprioceptive feeling when transposed. And transpositions are usually associated with changes in fingering as well, a fact that of course even more attenuates the relationship between structural identity and manual similarity. There is for instance a clear proprioceptive difference between the C major and B^b major triads; cf. exs. 3a and 3b. In C major the thumb starts/ends the rising/ falling root position triad constituents of the figuration and gives emphasis to the tonic, whereas the necessarily asymmetric fingering for B^b major, exhibiting a mismatch between structural and fingering pattern, slightly undermines the B^b major quality. Or consider the chromatic scale that no matter its equidistant steps and uniform musical motion seems to be irregularly divided into groups of two and three notes.

3

To give an idea of these playing patterns and the symmetries that may be inherent in them, and to study how they are correlated with auditive musical structures, four short passages have been analyzed by expert players with respect to how they are executed at a strategic sample of instruments - the piano, the violin, the double-bass, the guitar, the trumpet, the trombone, the flute, the clarinet, the organ - and when sung.

The passages presented to the informants were a two-octave rising/falling major scale, a rising/falling root position triad arpeggio through two octaves, and two conventional sequence chains built upon the scale and the triad, respectively. The former two passages feature octave transposition of the same material, and also upward motion followed by downward, while the latter involve transposed reiteration of identic or closely similar musical motifs. Thus all passages exemplify various types of structural symmetry, but to what extent will this auditive musical order survive the constraints associated with the peculiarities of the instruments and the chosen (or inevitable) way of execution, and turn up in the proprioceptive domain?

The musicians were asked to carefully write down all motions required to execute the passages and also to specify alternative playing patterns in addition to the one first entering their minds, alternatives that might perhaps be suitable for special purposes - besides articulation, the tempo is a most important consideration when deciding how to play. It should also be pointed out that on many of these instruments different ways of playing are associated with actual, physical differences with respect to the emitted sounds: the tones may be more or less affected as to loudness, timbre or intonation.

The musicians were further encouraged to transpose the given passages to keys requiring substantially different playing patterns - easier or more difficult, more or less orderly - and to take down in detail how these transposed versions of the material might be played.

Turning next to a selective presentation of the results of this inquiry, the pianist's handling of the material may be accounted for without further introductory comments. And having our previous observations on the constraints as well as artistic freedom associated with piano playing in mind as a model for the possible ramifications of proprioceptive patterning, the conditions for making music on the other instruments can be presented in less detail. To save space only the first, ascending parts of the four passages are given on the sheets showing the outcome; generally speaking, the same fingerings etc. tend to appear backwards on the way down (unless the musicians do not choose otherwise). But on closer consideration and for various reasons this correspondence is often questionable from the proprioceptive point of view.

The pianist's fingers are numbered 1-5 from the thumb to the little finger, and the right and left hand fingerings are given above and below the examples, respectively. Horizontal brackets show groups of finger motions (and by extension groups of notes) that belong together, that are separated from each other due to shift of hand position.

The rising C major scale demonstrates the fact that the position shifts in the right and left hand are never co-ordinated when playing scales.

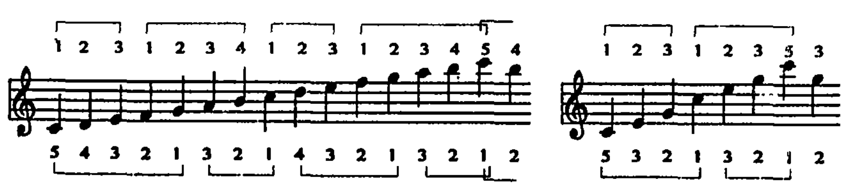

Figure 1: C major scale and triad for the piano

The A^b-major scale is less satisfactory from the manual point of view since it begins with an incomplete right-hand group and is topped by a single middle finger motion in the left hand. The B^b-major triad can be played with several fingerings, and yet it remains awkward. While the upwards and downwards fingering in scales and triads is generally the same, the manual feeling is distinctively changed when the motion is reversed, since subpositioning of the thumb is exchanged for superpositioning of the middle finger or ring-finger. Apart from the fact that the arm position must be changed, the keyboard allows of proprioceptive identity when a passage is transposed by an octave.

Turning to the melody sequence, the same motif tends to have different fingerings when played in different keys (and on different scale positions within the same tonality). It is also clear that the pianist to some extent can project either the neighbour-note or the leading-note motif inherent in the sequence by choosing a recurring fingering.

When playing the violin the hands have entirely different functions. The left hand is engaged in intonation along the neck of the instrument: higher pitches are played by pressing down the string with the fingers upwards along the string from the index finger to the little finger, by moving to upper hand positions on the same string, and/ or by changing to the next string, tuned a fifth higher. This means that the same note can generally be played in many different ways: the player chooses string/position so as to achieve the proper timbre, and selects position/fingering so as to arrive at a good pattern both with respect to the hand/finger motions as such and with respect to the bow motions, and to how these patterns fit with the musical structure. High notes may also be played as flageolets or harmonics, i.e., as partial notes selected by touching gently the string at certain points, dividing it into two portions oscillating separately. A further duty of the left hand is to supply a proper amount of *vibrato*.

The violinist's right arm holds the bow and (to say nothing of all other bowing niceties) activates the strings with a carefully chosen sequence of down and/or up motions and angle adjustments to touch the proper string. At first the down/up movements of the bow might seem to represent a symmetry, but the motion starting from the frog of the bow is potentially more powerful and may be used to achieve tones with quite harsh attacks. The bowing motions give rise to a second and also very complex patterning

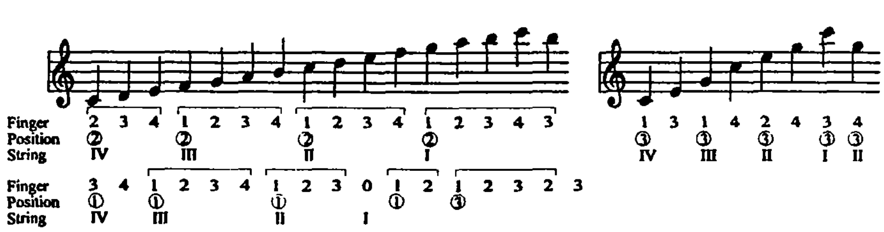

Figure 2: C major scale and triad for the violin

superimposed on the music, an articulative patterning that (though it is most conspicuous both for the player and the listener) will be left out of account here.

To sum up, violin playing means co-ordinating two systems of motions that are entirely different as to their nature and function, and that the musician strives to organize in patterns that represent the structure in ways that are both motorically convenient and artistically productive.

Due to the sheer size of the instrument, the inertia of the strings, and the fact that its (generally) four strings are tuned in fourths, double-bass technique emerges as an extremely modified violin technique. The long distances along the neck necessitate more frequent changes of position and also another fingering pattern - the ring finger and the little finger usually work together (which of these fingers that actually shortens the string depends on the musical context and on the training of the player) and the thumb is sometimes used to stretch the positions or to play flageolets.

Guitar playing offers another complement to the proprioceptive patterns of the violin. Again the left hand shortens the strings, but the six strings along the fretted neck are tuned in fourths with one interspersed major third. The right hand, plucking the strings, is also engaged in finger-work: the thumb generally plays the three lower strings, the little finger is hardly ever used.

When indicating fingerings on these string instruments, the fingers are numbered 1-4, beginning with the index finger; + refers to the thumb. The figure O means empty string, and a small circle refers to flageolet tones. The positions/frets are given by encircled arabic figures, and the strings, beginning from the lowest one, are indicated by Roman numerals.

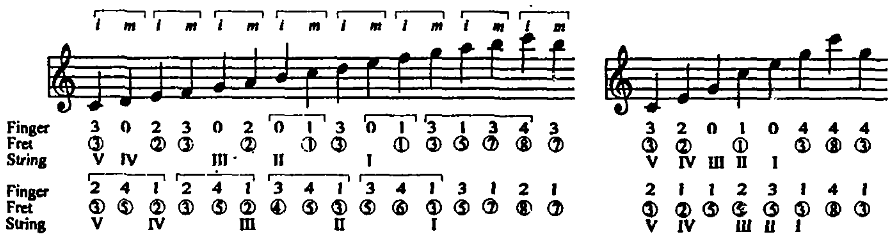

Figure 3: C major scale and triad for the guitar

Starting with the violin C-major scale, it appears that it is possible to devise more or less recurring groups of finger motions, but there is no octave identity from the proprioceptive point of view, and no true equivalence between rising and falling motion since the changes of position must necessarily be distributed in a different way. These observations are valid also for the scales of the double-bass and the guitar, though in the former case the fingering sequence is rather fragmentary due to frequent changes of string and hand position.

The playing patterns of the rapidly raising triad figurations exhibit little order. On the other hand, in violin sequences the fingering may reflect musical identity with proprioceptive similarity - the fingering expresses the neighbour-note aspect of the material. Transposition is associated with substantial differences in motion pattern on all these instruments.

Trumpet and trombone playing (and wind instrument playing generally) includes motions with lips, tongue, and diaphragm. Lip adjustments influence tone quality and intonation, and are crucial for overblowing, whereas the tongue is used for articulation: by using (or not using) syllables beginning with suitable consonants the amount of separating silence and starting attack can be controlled. The breathing pattern, finally, reflects the phrasing of larger musical units.

The trumpet is essentially played with the three middle fingers of the right hand, and the tube is lengthened to produce six further, progressively lower notes by depressing one, two, or three of the valves in the seven possible combinations. (The note three semitones below the original pitch can be played in two ways.) All notes above the bottom register are reached by means of over-blowing, recursively raising the pitch from which the chromatic lowering departs. As the intervals in the series of partial notes get ever smaller, the higher registers overlap each other more and more, which means that the same note can be played with various valve combinations. The sequence of finger combinations (some intervals may be played with no fingering change) is thus intimately related to, traversed by, the changes of overblowing register brought about by the lips.

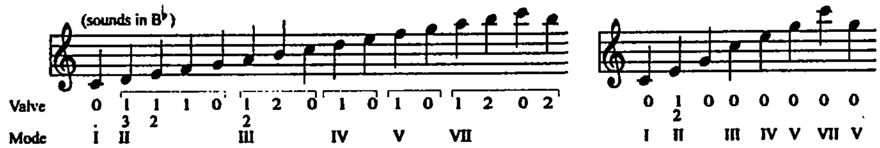

Figure 4: C major scale and triad for the trumpet

On the trombone the three valves are replaced by a slide that can be lengthened to six further positions. (On larger trombones this basic mechanism is complemented by a valve that lowers the pitch by a fourth.) Again, in higher registers the same note can be played with different slide positions, a fact that - combined of course with the concomitant lip adjustments to produce the proper register - may be used to modify the more or less jerky motion patterns of the right arm.

Figure 5: C major scale and triad for the trombome

The notation of trumpet fingering is somewhat confusing in so far as the valves are not ordered according to the extra tube length activated. The valve next to the mouth is depressed by the index finger (1), but lowers the pitch by two semitones, and the middle-finger valve (2) corresponds to a pitch just one semitone lower; the third valve operated by the ring-finger (3) lowers by one and a half semitone. The slide positions are indicated by the arabic numerals 1-7; the letter V refers to the extra valve. The over-blowing mode is specified by Roman numerals.

Apart from the fundamental difference between small finger/valve motions and large slide motions made by the arm, there are obvious similarities in principle between trumpet and trombone playing patterns. None of these (or any) brass instruments exhibit octave identity when it comes to proprioceptive patterning, and the way down the scales or triads is different from the way upwards due to various locations of the over-blowing shifts. Transposition means considerable changes of motion pattern: some scales, and especially some triads, involve less finger or arm action - the work is to a greater extent done by the lips controlling the over-blowing mode. Regarding sequences, however, the prospects for reflecting the same motif with a recurrent similar proprioceptive pattern are fairly good, especially on the trombone.

Woodwind instruments like the (transverse) flute and the clarinet are played by means of a system of (partly) key-operated holes that chromatically raise the pitch by shortening the acoustically effective part of the pipe, and the two hands co-operate intimately to produce the pitches. The left hand fingers are all used, whereas the right hand thumb only supports the instrument. The finger combinations corresponding to the various notes are quite intricate, and as a result of over-blowing the same note in higher registers may be played with different finger combinations, alternatives that involve small or quite substantial differences in timbre and/or intonation.

Apart from the basic difference with regard to the acoustic mechanism of tone excitation, the flute overblows in the octave, whereas overblowing on the clarinet (effected by opening a special hole) yields octave plus fifth. This fact means that the clarinet has a more complex system of holes/keys, and that clarinet playing involves more alternative fingerings and more gliding thumb or little finger motions between adjacent keys. As a result flute and clarinet fingering patterns tend to be quite different.

The intricate fingering combinations of woodwind instruments are hard to write down and hard to survey in all their details. In the present examples the initial finger combination is given in its entirety: the fingers are numbered 1-5 from the thumb to the little finger, and left and right hand configurations are found to the left and right of the vertical line, respectively. The combinations for the following notes are given as changes only: the figures indicate additional fingers that are pressed down (+) or fingers already depressed that are lifted (-).

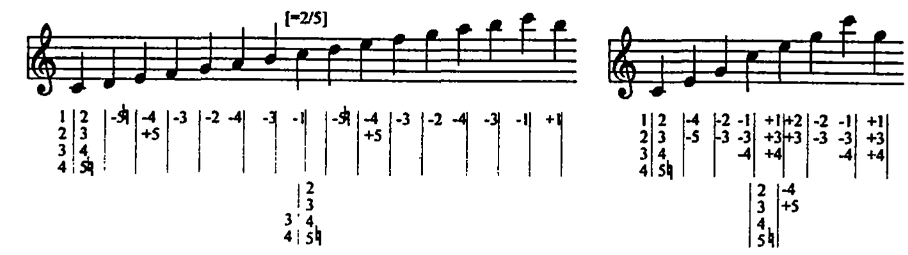

Figure 6: C major scale and triad for the flute

The fingering patterns of the flute show traces of octave identity; turning to the clarinet, which does not over-blow in the octave, no such correspondence is found. It appears that (especially on the flute) descending scales are generally associated with depressing the fingers, and for that reason they exhibit little proprioceptive resem- blance with their ascending counterparts, involving lifting the fingers. Transposition involves radical fingering changes. Due to the complexity of the two-hand combina- tions producing the different notes - the system implies that some intervals can be played with just one or a few finger motions, while others require substantial changes: several fingers have to pressed down and several have to be lifted - the possibilities to devise sequences of similar motion patterns corresponding to recurring musical material are slight.

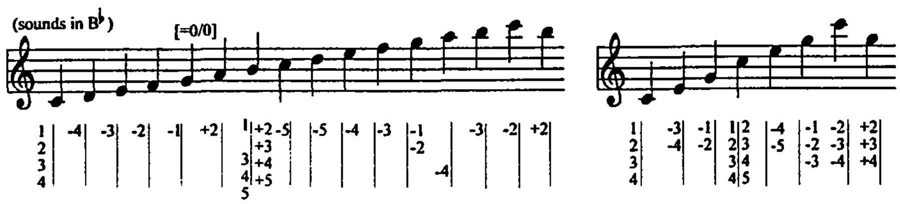

Figure 7: C major scale and triad for the clarinet

The organ pedals are basically played with right/left foot tip alternation. However, to make the right/left scheme more flexible and (when needed) to preserve *legato* articulation, you can also twist between tip and heel of the same foot, slide with the tips, and change foot or change from tip to heel (and the other way around) while holding a key depressed. For reasons of convenience one avoids to play the rightmost keys of the two-and-a-half octave keyboard with the left foot, and vice versa. Tempo and desired articulation are very important considerations when devising the foot movement pattern for a passage - to the extent that legato patterns involve changes on the same depressed key they are slow, and the additional time-points associated with the silent change motions seem to make the rhythm more complex.

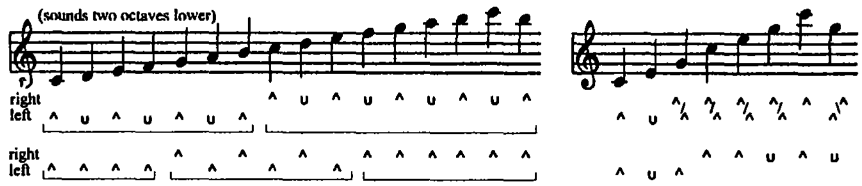

Figure 8: C major scale and triad for the organ pedal

The upper symbols (the meaning of which should be evident) in each row refer to the right, and the lower to the left foot. The first way of execution featuring frequent shifts between tip and heel, as well as slides between keys and exchanges on depressed keys, carries a proprioceptive feeling of *legato* and are also used for *legato* articulation. The patterns on the way down tend to be somewhat different from those shown for the direction upwards, and while octave transpositions may to some extent be identic in terms of playing motions, other transpositions tend to produce quite different patterns. Turning finally to the sequences, the recurring motif can only in some cases be proprioceptively identified by means of a similar playing pattern.

Though they are not overt, there are certainly motions, and proprioceptive sensations associated with them, also when you sing. Rising intervals, implying increased effort, are very different from their would-be symmetric counterparts, the relaxing falling intervals, and large intervals generally present a challenge to both vocal cords and tonal imagination. In singing there may be more or less distinct register shifts - registers within which the manner of tone production is different - and the perceived locus of the tones appears to shift from chest to head. And apart from the articulation required by the text, the voice is supported if the singer in his/her mind selects and lets the tone be more or less tainted by the vowel quality that is optimal for the pitch at hand.

The proprioceptive sensations associated with singing are likely to be less intersubjective than those associated with instrumental playing. To some extent these differences depend on technical training or personal habits, but more important is the fact that professional male and female singers use different tone production techniques. Thus one might expect crucial variances with respect to proprioceptive patterning between male and female singers, and presumably also between sopranos and altos, and between tenors and basses.

That the way down a scale or a triad is very different from the taxing way upwards is obvious, and so is the fact that octave transpositions (and indeed all transpositions by larger intervals) are associated with decisive differences in proprioceptive feeling. This soprano preferred a vowel shift for a few relatively high notes in the scale, and also a shift from the prevailing [a] quality at the top note in the D-major triad, introducing a flute-like register. In the sequences the dotted line refers to a register shift that must be smoothed out in favour of a gradual change from chest to head register during the entire ascent; the slurs and the *diminuendo* sign indicate imagined phrasings and dynamic inflections that may help to achieve an even sound.

Of the instruments studied, only the piano exhibits full proprioceptive identity when material is transposed by the octave; some such constancy is also found on the flute. All instruments (including the pitch continuous singing voice) are characterized by the fact *that transposition to different keys implies more or less substantial changes as to the* proprioceptive patterning. Upward and corresponding downward motions are to various extent and for various reasons proprioceptively different on all these instruments. Depending on the constraints of the instrument and on the technical ingenuity of the player, motivic material recurring on different pitch levels can to some extent be reflected by means of identic or at least similar motion patterns.

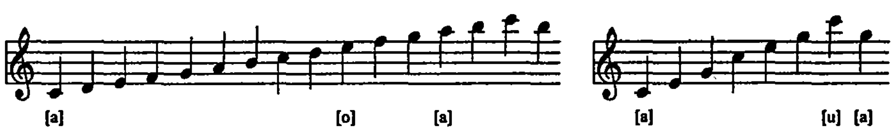

Figure 9: C major scale and triad for the soprano

The net result of this investigation is thus that octave transposition and transposition between keys, inversed motion, and reiteration of identic or closely similar material - features associated with aural musical symmetry in broad sense - tend to have few and imperfect correspondences in the proprioceptive domain. To a great extent the hands, arms, feet, lips, tongues and throats of musicians deal with other structures than their ears and eyes, and if it is true that music ultimately resides in the mind, the musicians certainly have a rich and bewildering representation of it.

Acknowledgement

Since no individual musicologist knows the technical peculiarities of various instruments in sufficient detail, comparative work in the field of musical idiomatics must always be a team-work. I am much indebted to my informants for their patience and interest - Anders Frostin (violin), Kristina Martensson (double-bass), Antonio Rodrigues (guitar), Roger Andersson (trumpet), Leif Andersson (trombone), Anders Ljungar-Chapelon (flute), Christophe Liabäck (clarinet), Janake Larson (organ), and Evy Brahammar (soprano). I was in fact given far more know-how than could be used in this survey study.