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Psychological Evaluation of Non-Conventional Notations and Keyboard Tablatures

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Abstract: Guitar tablatures have been widely used for centuries. Not so keyboard tablatures, presumably because no international standard has emerged from the diversity of published proposals. Recent developments in computer technology have made it possible to test keyboard tablatures in a way that is both scientifically and ethically sound. An automatic transcription system would allow piano students unlimited access to music in a given non-conventional notation or tablature. A longitudinal experiment is proposed that would take advantage of such technology to study the effect of individual notational manipulations on adult beginner pianists' acquisition of performance and sight-reading skills. Possible manipulations involve octave equivalence, one-to-one versus many-to-one correspondence between pitches and chromatic notes, time- and pitch-proportionality of spatial relationships between noteheads, visual discriminability of symbols, number of staff and ledger lines to be learned, and (a)symmetric representations of diatonic scales. Implications of the loss of enharmonic information in chromatically based notations are discussed.

1 One Notation System or Many?

Of all the signs and symbols involved in composing, arranging, performing, analysing, and understanding music, the most important, in a practical sense, are without doubt the ubiquitous staves, clefs, noteheads, accidentals, stems, flags, beams, rests, phrase marks, slurs, and articulation marks of music notation. In this article, I ask whether or not conventional music notation – in particular, diatonically based pitch notation – is the most appropriate and efficient way of representing musical pitch relationships. I then examine some procedures that would need to be followed in order to develop and test alternatives to conventional pitch notation.

This paper is not about reforming conventional music notation. It would be neither desirable nor practical to attempt to usurp the dominant position that conventional Western notation has attained. Millions of musicians are not going to learn a new notation system in the foreseeable future, no matter how much better a non-conventional system may turn out to be by comparison to the conventional system. Conventional music notation facilitates musical communication across linguistic and cultural borders. It would be foolish to attempt to jeopardize the widespread acceptance of such a useful international standard.

But universality has its down side. To use only one notation system is to see all music within the same frame of reference. A standard, chromatically based alternative to conventional notation would allow musicians to see musical patterns from new angles, just as pitch-class set theory (Forte 1973) enabled new insights into the structure of atonal music. Similarly, the ability to speak different languages allows one to separate ideas from the sounds of the words with which they are expressed, and to contextualize ideas within different cultural settings.

Reading music expressed in a chromatically based notation system may influence performers' perceptions of tonal relationships in the music, and consequently, their understanding of the nature of tonality. We don't know very much about musical bilingualism, especially in the case of tonal western music for which the standard repertoire is notated according to a highly uniform system of conventions. It would be interesting to study people who are fluent in both conventional notation and a non-conventional system such as *Klavar* (Pot 1965), exploring whether and how their bilingualism affects their understanding and perception of music.

Read (1987) lists hundreds of forgotten music notation proposals from the past few centuries. The historic record is one of musicians (and would-be musicians) repeatedly and independently "inventing" systems that are subsequently ignored by the musical establishment. This raises the question of whether the current universality of conventional music notation is due to its inherent superiority (as Read assumes) or to sociopolitical forces leading to suppression of competing systems and discouragement of new systems. Pursing a linguistic analogy, the international dominance of conventional music notation may be compared to the historical enforcement of Parisian French throughout France, or to the more recent – but equally questionable – practice of encouraging the citizens of linguistically or dialectically diverse countries such as Canada and Germany to speak a single standard language in their everyday interactions, thereby marginalizing historically rich dialects such as French Canadian and Bavarian. Clearly, the loss of such dialects would have enormous and irreparable cultural repercussions, and could not be justified in terms of inherent properties of those dialects.

But is it reasonable to make such analogies? Music notation and written language differ in the nature of meaning that they represent (Rakowski 1988, Sloboda

1985). Linguistic meaning is more denotative and referential (statements can be true or false), while musical meaning is more connotative and non-referential. Musical and linguistic meanings are constructed from different kinds of unit (e. g., notes versus phonemes). Linguistic phonology is more arbitrarily linked to syntax and semantics (in principle, a given acoustic utterance can take on any meaning at all) than musical phonology (in which for example certain note patterns – scales and intervals – are *a priori* more likely to occur than others). Such differences aside, both (notated) music and (written) language have an important aspect in common – both involve communication and expression by means of symbols whose meanings are to a large extent arbitrary. From this point of view, the analogy between written languages and music notation systems is an interesting and valid one.

On both the linguistic and musical sides of the analogy, an optimal path needs to be navigated between two undesirable extremes. One extreme is represented by a single, narrow, inflexible universal language. The opposite scenario is a diversity of linguistic subcultures without a *lingua franca*. In the case of music, the point of the optimal balance is not clear. The notational innovations of 20th-century composers have enriched our notational palette (Cope 1976, Kontarsky 1972), confirming that conventional notation is capable of further evolution to accommodate the demands of contemporary styles. But for tonal music, the notation system appears to be set in stone. Are we are swinging too far in the direction of a single system?

2 History and Features of Conventional Notation

Conventional music notation has a long, complex, and well-documented history (Bent et al. 1980, Read 1974). It evolved under the influence of a range of forces that varied at different times and in different places. Its evolution has always been strongly coupled to the evolution of the musical language itself. As new musical styles emerged, new ways had to be found for writing them down.

But the system has inbuilt problems that can never be solved by a gradual evolutionary process (Brennink 1992, Gaare 1997, Koppers 1989, Parncutt and Stuckey 1992). First, vertical distance on the staff does not correspond in a simple way to pitch distance in semitones or to physical distance on the piano keyboard: a given interval on the staff (e. g. a third) can have various qualities (major, minor, augmented, diminished) depending on the key signature and any accidentals appearing between the note and the previous barline. Other commonly cited drawbacks of conventional notation include its failure to take advantage of octave equivalence (tones an octave apart are seldom similarly notated);

the use of two symbols (note plus accidental) to specify one pitch; and enharmonics, by which the same note in the chromatic scale may be notated in two quite different ways.

Conventionally literate musicians do not regard any of this as a problem. The conventions of music notation, at least for tonal music, are widely regarded as fixed and unchangeable, and the questioning of notational conventions has something of a taboo status. Sober musicians, musicologists and music theorists wisely avoid facing the somewhat embarrassing possibility that notational conventions are arbitrary and could possibly be improved upon. Worse still is the prospect of interfering with the system within which great composers wrote their music. The texts of the musical canon are regarded as almost sacred. Would J. S. Bach, for example, approve of his music being transcribed into a different notation system?

The origins of this climate of notational conservatism may be traced to historic changes in music performance practice. The main features of conventional notation for tonal music were finally established during the eighteenth century. During the nineteenth century, there was a gradual transition in the European music performance tradition from a predominately *creative* art, in which teachers generally composed and improvised, to a *reproductive* art in which teachers focused on the interpretation of existing scores (Gellrich 1992). This development brought with it an increasing respect for the scores of great masterworks. In the twentieth century, musicians have tended to specialize as either composers, performers, musicologists, or music theorists; and performers have increasingly split into two separate kinds, interpreters (especially in the "classical/art" music tradition) and improvisers (especially in jazz and popular music). The tendency for "classical/art" composers not to perform, and for performers not to compose, has placed an increasing burden on the score as a carrier of essential musical information. One result of this development seems to have been an exaggeration of the importance notational artefacts such as enharmonic spellings.

3 Enharmonic Spelling

Chromatically based music notation systems lack enharmonic distinctions, by which for example C♯ and D♭ have essentially the same pitch but very different visual forms when notated. How would the removal of enharmonic information from musical scores affect their ability to represent musical structure and meaning? How would it affect the sound of the music played from the score?

To answer these questions requires a clear understanding of the nature and origins of enharmonic equivalence relationships. Unfortunately, as I will attempt to show, enharmonicism is currently surprisingly poorly understood, even in the

most sophisticated musical circles. Both performers and theorists routinely explain matters of musical meaning and interpretation with reference to enharmonic spellings, without being able to offer a clear, definitive statement of the difference between competing spellings, or the rules according to which they are determined.

A simple, well-known example is the C♯ in the bass line of measure 7 of the first movement of Beethoven's Eroica symphony in E♭. The note supports a diminished triad C♯3-B♭3-G4, functioning as a chromatic neighbor to the following dominant seventh chord D3–B♭3–F4–A♭4. When the diminished triad reappears in the recapitulation, it progresses instead to a new dominant seventh chord, C3–B♭3–E4–G4; the diminished triad is reinterpreted as a chromatic pivot for a passing modulation from Eb major to F major. The bass is still notated C♯, but its exit function becomes that of D♭, the new ♭6 scale degree. The note lasts for two bars, so Beethoven could easily have notated an enharmonic change to Db at the second of these bars; but it seems that (here and elsewhere) notational clarity and expedience were more important to him than enharmonic pedantry. In music-theoretic discussions of this passage, it is impossible to refer adequately and concisely to this note, because there is no single, well-known word or symbol for the note between C and D (although numerous possibilities have been proposed; see Parncutt & Stuckey, 1995). The commonly used shorthand "C♯ becomes D♭" gives the misleading impression that the (implicit) enharmonic change *adequately represents*, and perhaps even *causes* (is the reason for), the note's functional change. In the following paragraphs, I will argue against both these tacit assumptions.

To introduce my argument, I will first look at the historic origins of enharmonicism, and associated historic tensions between the diatonic and chromatic scales. Twelve-tone chromatic keyboards first appeared in Europe in the late 14th century (Scott 1986). But it may be argued that the chromatic scale, or at least the underlying idea, dates to Ancient Greece. As early as the 4th century BC, Aristoxenus advocated that the perfect fourth interval be divided into *exactly* two whole-tone steps and one half-tone step (Barbera 1986). When realized physically, this idea leads to an intonation that is closer to equal temperament than the tuning of most modern pianos (cf. Ward and Martin 1961), keeping in mind that a just fourth (frequency ratio 4:3) differs from its equally-tempered equivalent by only 2 cents.

The notation system developed by Guido in the 11th century was, of course, diatonically based. It did not include lines or spaces for non-diatonic notes, so each could only be notated relative to its upper or lower chromatic neighbor. During the middle ages, non-diatonic notes became increasingly frequent. At first, spellings tended to be chosen that required a minimum number of accidentals (in fact, accidentals were avoided altogether for centuries, and exact pitches instead determined by the rules of *musica ficta*). The principle of minimizing the number of symbols is the oldest, simplest and most practical of all principles of enharmonic spelling.

In recent centuries, tonal music has become far more complex than Guido could ever have imagined. Chromaticism has been integral to the structure of tonal music since the 18th century (Baker 1993). Even the chromatic aggregate (all 12 pitch classes within a few bars of music) can be traced to the 18th century (Burnett and O'Donnell 1996). Enharmonic ambiguities have existed since Gesualdo, and have been common since the nineteenth century.

Modern conventions of enharmonic spelling are widely adhered to by literate musicians. But because musicians' and music theorists' knowledge of enharmonic conventions is acquired primarily through practice rather than theory, and is primarily procedural rather than declarative, explicit statements of the underlying rules are rare. In the absence of a clear definition, however, music-theoretical arguments based on enharmonic spellings lack a solid grounding.

A possible basis for the definition of enharmonic spellings is the *Tonnetz*. Riemann (Hyer 1995, Lewin 1987, Wason and Marvin 1992) and Longuet-Higgins (1962) developed two-dimensional arrays of pitches separated by perfect fifths in one dimension and by major thirds in the other. Along each dimension, spellings gradually acquire sharps in one direction (along the fifths axis ...E-B-F$^\sharp$-C$^\sharp$..., and – more quickly – along the thirds axis ...E-G$^\sharp$-B^x-D^x...) and, symmetrically, flats in the other direction. Enharmonic spellings may be determined systematically from such a network by minimizing distances traversed in 2-D space – reminiscent of Riemann's (1914) idea that harmonic relationships are actively conceptualized by *beziehendes Denken* (Eberlein 1992). But there are two major problems here. First, such an approach cannot account satisfactorily for musical temporality. Casual perusal of, for example, the romantic piano literature suggests that enharmonic choices depend on the specific *temporal* context in which a note appears – that is, on the notes and chords that immediately precede and (to a lesser extent) follow each spelling. Second, the *Tonnetz* approach can only account for what might be termed *harmonic* effects. It cannot explain, for example, why Mozart generally notates a lower chromatic neighbor to scale degree 3 in a major key as $^\sharp$2 rather than $^\flat$3. This latter aspect of enharmonic spelling involves voice leading and may aptly be termed *melodic*.

An attempt to separate and generalize melodic and harmonic contributions to enharmonic spellings was made by Parncutt and Stuckey (1992). According to our "melodic rule", semitones should preferably be notated as minor seconds (diatonic semitones, e. g., C – D$^\flat$) rather than as augmented unisons (chromatic semitones, e. g., C – C$^\sharp$). According to our "harmonic rule", intervals of four semitones should preferably be notated as major thirds rather than as diminished fourths.

We went on to propose that when these two rules conflict, as they commonly do, intervals relative to tonally stable points of reference (e. g., scale degrees 1 and 5) predominate over weaker reference points. For example, the note between G and

A should be notated G$^\sharp$ in a context where E and A are more tonally stable than G and C, and as A$^\flat$ in a context where G and C are more tonally stable than E and A. Clearly, different composers weight the two rules differently; a systematic study of compositional practice with regard to enharmonic spellings has not yet been carried out, but would now be a relatively straightforward matter involving the searching of large musical databases using software such as Humdrum (Huron 1994).

When the rules of enharmonic spelling are explicitly stated, their intrinsic vagueness and ambiguity become evident. It is not uncommon in tonal music, for example, for pitch classes E, G, A, and C to have about the same degree of tonal stability as each other. In such contexts, the choice between G$^\sharp$ and A$^\flat$ may be quite arbitrary. Convention does not clearly indicate which of the two available alternatives is the "correct" one. So composers must make what psychologists call a *two-alternative forced choice*. If a composer feels that a given note is, say, 60% G$^\sharp$ and 40% A$^\flat$, then G$^\sharp$ will probably be chosen to notate it. The notation system does not give the composer any opportunity to tell performers and musicologists anything about the residual, unnotated "A$^\flat$-ness" of the note. This renders the widespread practice of music-theorizing on the basis of enharmonic spellings a somewhat risky business.

Perhaps the most important factor in the choice of enharmonic spellings is convenience for the performer. Composers want their music to be played, and it helps if it is easily legible! When Wagner penned the orchestral score of *Tristan und Isolde*, for example, he varied his enharmonic spellings for the Tristan chord depending on which instruments were playing it. The different enharmonic spellings of the Tristan chord in the original score are consistent with a pragmatic, performance-oriented approach to notation: Wagner notated the chord in such a way that musicians familiar with the quirks of diatonically-based notation can read it most easily.

We might therefore seriously question those innumerable enharmonically based music-theoretic arguments that have been advanced to explain the Tristan chord (at its first appearance in the opera: F3-B3-D$^\sharp$4-G$^\sharp$4 in an ambiguous A-minor context). One example of many is the recent claim by the well known and respected Schenkerian theorist John Rothgeb that "the outer voice interval of the TC [Tristan chord] is specifically an augmented ninth, not a minor tenth, and these two intervals differ radically in tonal music, not only in function but in sheer sonority" (1995, abstract). Such arguments not only lack definition – they are unscientific in the sense that they cannot be falsified, because no rules of enharmonic spelling are explicitly stated.

A valid explanation of the musical meaning of the Tristan chord, or of any other chord in a context whose tones can all be accounted for within the chromatic scale, can only be based on the structure of that context itself. The most

straightforward and transparent way to understand the sound and function of the Tristan chord is to regard it as a half-diminished seventh in an unusual context.

It follows more generally that enharmonic spellings should play no intrinsic role in the theory of harmony, beyond rudimentary considerations of notational convention. It was pointed out as early as the mid-19th century by theorists outside the mainstream (Vincent 1894, Weitzmann 1861; both cited in Wason 1988) that the chromatic scale is the most appropriate basis for tonal harmonic theory, and that the distinction between A♭ and G♯ "liegt nur mehr in der Schreibart, nicht in der Sache selbst" (Singer 1847). Chromatically based tonal theory is consistent, for example, with Liszt's well-known point that a consonant triad (or, more generally, any chord) can, with suitable voice leading, progress satisfactorily to any other consonant triad in the chromatic scale. The proof of the pudding is in the eating: it is possible to construct comprehensive and quite sophisticated harmonic theories that make no reference whatsoever to enharmonic spellings, yet have the potential to "explain" all possible tonal configurations within the chromatic scale (e. g., Eberlein 1994, Forte 1973, Koppers 1989 and 1998, Krumhansl 1990, Lerdahl 1988 and 1996, Parncutt 1989 and 1997, Pot 1970, Sikorska 1963). But in the absence of a widely accepted, chromatically based music notation, it has not yet been feasible to develop a fully worked out, chromatically based harmony text suitable for undergraduate use.

Basing music-theoretic arguments on enharmonic spelling can be problematic in quite subtle ways. Harrison (1995) has proposed that any chord might be called an "augmented-sixth" that "depends upon the augmented-sixth (or diminished-third) interval for all or most of its tonal energies" (p. 184). This definition of augmented-sixth chords usually works well in practice. But because it is expressed in terms of enharmonic spellings, it depends crucially on *their* definition and inherent ambiguity. Harrison's article does not contain, or refer to, a statement of the rules of enharmonic spelling, nor does it discuss of the implications of enharmonic ambiguity for the proposed definition of augmented sixth chords. The definition thus relies somewhat uncomfortably on the enharmonic choices made by composers. That these are sometimes arbitrary is clear from Harrison's observation that, when augmented sixth chords act as enharmonic pivots, composers rarely indicate the enharmonic change, and tend to spell the chord according to its entry rather than its exit function.

What is the link between enharmonic notation and *intonation*? In a well-rehearsed performance, the Tristan chord, like any other sonority, should sound the same regardless of how it is notated enharmonically. Introspection would suggest that musicians first read the score to find out where to put their fingers, then listen to the sounds they are making in order to get the intonation right. In the end, what matters is the sound, not the notation. If there are obvious errors

in enharmonic spellings, musicians can and will correct them; in the end, the sound should not be affected.

The findings of experimental studies on intonation (summarized e. g., by Parncutt 1989, Sundberg 1982) do not generally allow for intonation to be predicted on the basis of enharmonic spellings. The note G♯ (e. g., as part of an E7 chord) is sometimes intoned higher than A♭ (e. g., as part of an F-minor chord) and sometimes lower. The first kind of intonation approaches the Pythagorean ideal, and can be observed, for example, in fast violin music. The second kind approaches just intonation, and can occur in slow choral passages without vibrato. Clearly, then, enharmonic spellings of intervals do not correspond to frequency ratios (cf. Agmon 1990).

Closer examination reveals an even greater complexity. It would appear that *every intonation is a compromise* (Terhardt 1974). Depending on the specific syntactic situation, a performer may be attempting to minimize roughness, optimize the clarity of component pitches, approach the familiar tuning of pianos, reflect voice leading at different structural levels (including anticipating a tone of resolution), discriminate between the tuning of simultaneous and successive tones, exaggerate differences between similarly-sized intervals such as major and minor thirds, grapple with physical or technical limitations, enhance timbre and expressiveness by the use of vibrato, or follow known conventions of emotional expression and communication – or any combination of these (cf. Fyk 1995). Enharmonic spelling is conspicuous by its absence from the list of factors that have a direct, causal effect on intonation. Optimal intonation is produced by listening, not by looking at the score.

In summary, enharmonic distinctions do not yield any tangible or fundamental insight into the musical meaning of a note, passage, or piece. They do not say anything reliable about a piece's *structure* as perceived by listeners. They do not prescribe, and should not influence, *intonation*. Meaning, structure and intonation in western tonal music are primarily encoded in, and determined by, the pitch-time patterns notated in musical works, where pitch is measured relative to the chromatic scale. In this sense, enharmonic distinctions may be regarded as superfluous – as notational artefacts.

The enharmonic spelling of a note, like its meaning, depends directly and exclusively on the pitch-time configuration of its *context*, which may be defined loosely as the pattern of simultaneous and successive pitches in the few seconds surrounding the event (the "psychological present", Fraisse 1963) and extending to the longer time-spans of the Schenkerian middleground. That context can in turn be represented directly and unambiguously by reference to the chromatic scale. Enharmonic spelling does not depend directly on musical meaning, nor does meaning depend directly on enharmonic spelling; the relationship between these is *indirect*, and mediated by context.

Each enharmonic spelling is the result of a *forced choice* between two alternatives. In the language of computer science, such spelling choices encode only one "bit" of information. Of course, many bits of information are required to specify a note's musical meaning and optimal intonation. This information is encoded in the note's context, not its enharmonic spelling.

Correct enharmonic spelling is important for the *legibility* of conventional notation, and spelling choices in ambiguous cases may also tell us interesting things about the notational style of a composer. But enharmonic spellings do not carry useful information about correct performance that is not already available from the contexts in which they appear; nor do they carry *reliable* information about composers' intentions.

Enharmonic spellings are byproducts of a long tradition of notating chromatically based music within a diatonically based notation system. Guido, on emerging from a time machine, would be astonished (and possibly rather flattered) to find that diatonically based notation and terminology are still generally regarded as the most appropriate basis for theorizing about tonal music. Tonal music is written relative to the diatonic scale primarily as a matter of convention and convenience. The mere fact that all tonal music can all be played recognizably (and mostly quite convincingly) on the piano (provided one has enough fingers) is sufficient demonstration of its underlying chromatic basis.

4 Critical Evaluation of Conventional Music Notation

In the light of these observations, it is reasonable to ask a fundamental but neglected question: *Does conventional music notation accurately represent tonal music?* For the past few centuries, we have not been in a position to answer to this, because Western music notation has been standardized to the point where other notations have almost died out. There has been almost nothing to compare it with.

But even without comparisons it is possible to draw conclusions. From the point of view of performance, some features of conventional notation, such as its failure to account in a straightforward way for octave and enharmonic equivalence relations, would tend to hinder the transfer of information from score to performer, and hence from composer or arranger to performer. Possibly as a result of such problems, many good musicians never become good readers (Sloboda 1978). Young instrumentalists' failure to grasp the more complex features of conventional notation may impede their progress and contribute to drop-out rates; but in the absence of a standard non-conventional notation with which conventional notation can be compared, studies on the acquisition of music performance

expertise (such Ericsson et al. 1993, Sloboda et al. 1996) have not been able to address this issue.

From a theoretical perspective, and for similar reasons, conventional music notation is not necessarily the most efficient way to represent relationships and structures that listeners *perceive* in music (Koppers 1989 and 1998, Parncutt and Stuckey 1992). If tonal music is based on interactions between sonorities and melodic fragments, each of which is a subset of the chromatic scale – and of course the diatonic scales upon which conventional notation is based are themselves subsets of the chromatic – then one might expect a notation based on the chromatic scale to represent those patterns more clearly than a diatonically based system.

In the remainder of this paper I will address practical and theoretical issues surrounding notations based on the chromatic scale. I will refer to the history of reform proposals, and consider what might be involved in the systematic testing of different non-conventional notations. I will then develop some hypotheses that might be tested in such an investigation, based on a range of practical, musical, and psychological considerations.

5 History of Reform Proposals, and their Failure

The need for a standard, chromatically based alternative to conventional music notation has been recognized by hundreds of individual musicians over several centuries (Brennink 1983, Gaare 1997, Read 1987, Reed 1997, Szczepanowska 1963, Wolf 1919). But "notation inventors" have differed widely in their assessment of the virtues and flaws of conventional notation, and which aspect(s) of the system they would like to see changed. Until now, it has not been possible to agree on any single alternative to conventional notation, and none has achieved widespread international acceptance. Two main reasons may be cited.

First, it has not been practically possible to transcribe large quantities of music into different notation systems for comparison. This is an important point, for it would be unethical to expect an experimental subject to spend months or years becoming fluent in a music notation system which may never be accepted by most musicians and for which the repertoire of printed music is limited. Two isolated exceptions to this rule merit consideration: *Klavar*, also called *Klavarskribo* (Pot 1965, some 25 000 editions, printed in Holland since the 1930s), and Ailler-Brennink Chromatic Notation (Brennink 1976, several editions printed in Switzerland and Canada). *Klavar* in particular continues to have a surprisingly large following in Holland and in other isolated pockets in the world. The staves upon which these notations are based are presented in Figure 1.

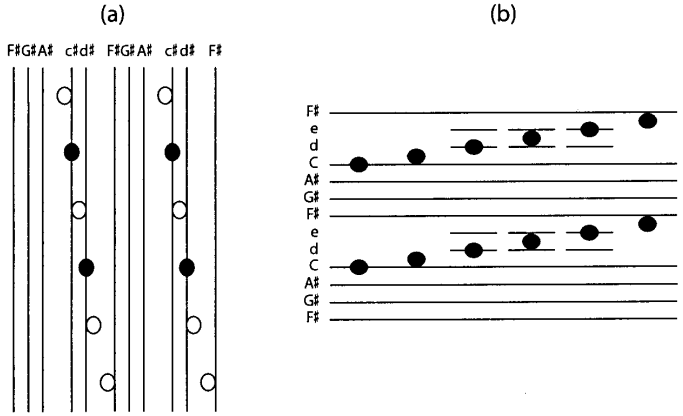

Figure 1. Staves used in (a) Klavar and (b) Ailler-Brennink Chromatic Notation. In each case a chromatic scale is notated from C to F, in octaves. Labels for staff lines (upper case) and ledger lines (lower case) are for illustration only and are not part of the notations. Rhythm notation is omitted.

The success of a notation system may not necessarily be reliable evidence of its quality. In the above two cases, the notation's success was due not only to its inherent merits but also to the time and money devoted to its promotion by its "inventor" and champion. With the benefit of hindsight, it is clear that both notations have clear problems that could have been avoided.

Three drawbacks of *Klavar* come to mind. First, it has too many staff lines (one for every black key!), leading to unnecessary clutter in complex scores. Second, as in conventional notation, pitch intervals are not exactly proportional to their size in semitones (the distance between B and C, and between E and F, is as big as a whole tone elsewhere on the staff). Third, the notation is too radical, changing both pitch and rhythm notation when changing pitch notation only would have sufficed.

The main problem with *Ailler-Brennink Chromatic* Notation is its arbitrary choice of staff lines (F♯ G♯ A♯ C) and ledger lines (D E). The logic of the staff would be more apparent if it were transposed through a semitone, shifting the staff lines to F G A B and the ledger lines to C♯ D♯ (Parncutt 1996). Even then, the relationship between the staff and the piano keyboard (or the physical structure of most other musical instruments) is quite complex: the staff lines correspond to white keys, and the ledger lines to black. Why should a musician put in

months of work to learn a system of this kind when simpler non-conventional options are available?

Returning to the question of why it has not yet been possible to agree on alternatives to conventional notation, a second main reason is that, until now, there has not been a sufficiently systematic and thorough attempt to compare the various documented notation proposals. Brennink's (1983) comparison of notation systems was problematic, given that he had already developed his chosen favorite notation and published it in 1976 – before undertaking the survey – and that he developed and applied the criteria to evaluate the different notations himself. In this light, it is no surprise that his evaluation procedure chose his own notation as the best! Read (1987) presented the most comprehensive coverage so far of non-conventional notations, but did not to attempt to compare them systematically. To do so would have contradicted his firmly-held belief in the superiority of conventional notation over all alternatives ever proposed.

More recently, Keislar (1994) detailed the processes that would need to be followed to evaluate and compare different notations. Some of the recommendations in this document are now being implemented by an Evaluation Committee within the Music Notation Modernization Association (Johnston et al. 1996).

As promising as this latest development may seem, a crucial ingredient is still lacking: a thorough, longitudinal study of music learning using non-conventional notations. Music reading skills involve a sensitivity to structural properties of the music as represented by the notation (Sloboda 1984) and can only be acquired gradually (Sloboda et al. 1996). But the empirical comparison of different notation systems in everyday musical contexts has so far only been piloted (Reed 1991, 1992, 1994). No-one has yet investigated the learning and use of non-conventional systems over extended time periods – presumably because no music student will, or should, devote hundreds of hours to learning music in a notation system for which only a limited repertoire exists in print. Until now, it has generally not been possible to test non-conventional music notations in a way that is both scientifically and ethically sound.

6 Modern Possibilities for Automatic Transnotation

Recent technological advances could allow this final hurdle to be jumped. Music can now be scanned into a computer and entered to conventional score printing programs (e. g., Carter 1993–94, Correla 1995–96). Software tools are available that would allow, with a finite amount of further programming, such music to be transcribed automatically into a range of non-conventional formats, and clearly printed (although some user interaction would doubtless still be needed to

adjust the appearance of the final image). A music transcription or *transnotation* system of this kind could solve the practical and ethical problems that have so far prevented the staging of a full-scale longitudinal study on the practicality and effectiveness of non-conventional notation systems.

Computer-based transnotation would not be as easy as buying a score off the shelf, but it would certainly be much easier than transcribing by hand, or arranging for a musician to write out a transcription. A carefully developed, flexible software tool, with clear documentation and easily available technical support, would have considerable market value, the main consumers being amateur pianists and keyboardists.

A computer-based system might work as follows. Input the music, using a scanner, into a standard music processor. Check that is has been input correctly by playing it back through MIDI (*proof hearing*). Automatically generate a preliminary image in a chosen non-conventional notation, in which noteheads are correctly positioned on staff lines, and other features of the image (stems, beams, slurs, and so on) are positioned similarly to the original score (cf. Charnassé 1981). Finally, allow the user to move these other features around the screen – to flip stem directions, and so on – to avoid overlap and clutter before printing out.

7 General Purpose Notation or Keyboard Tablature?

Even if such a system were up and running, it would still be premature to investigate and compare *general-purpose* non-conventional notation systems empirically. Different instruments have different notational requirements. An optimal notation for the flute may not be optimal for the organ, and vice-versa. It would therefore be necessary to compare several representative instruments (including the voice).

Such a study would be very expensive to carry out thoroughly. If, say, 10 different notation systems were each to be tested on 7 different instruments, with 7 adult beginners learning 10 pieces for each system/instrument combination, and each student taking 4 lessons per piece at a cost of DM 50 per lesson, the total bill for lessons would be in the vicinity of DM 1 000 000!

The bill would be reduced to more reasonable level by limiting the study to one instrument and testing candidates on one *special-purpose* notation. The number of systems to be tested could then be reduced (say, to 7). The total bill for lessons would then fall by an order of magnitude, to something in the vicinity of DM 100 000.

Keyboard instruments would appear to be the most appropriate focus for such an initial study. Keyboard tablatures have been in use for centuries (Read 1987 includes numerous published examples). But they have never become mainstream, presumably because of the difficulty of agreeing on one of the several possible versions.

The only instrument family for which tablature is already commonly used in western traditions is that of the guitar and lute. On these instruments, the relationship between conventional music notation and finger/hand-positions can be very complex. This makes tablature much easier to learn than conventional notation, at least for beginners. Higher-level classical players tend to prefer conventional notation, because it is more similar to a pitch-time graph, and so represents the music in a way that more closely resembles our perception of it. Conventional notation also makes it easier for guitarists and lutenists to work together with other musicians. If a standard keyboard tablature existed, its use might similarly be limited to lower skill levels; but, given the large market of amateur pianists, the exercise of developing the tablature would still be worthwhile.

8 Predicting the Differential Effectiveness of Non-Conventional Notations and Keyboard Tablatures

Figure 2 presents a selection of eight graphic notations and keyboard tablatures. I have created them for the present purpose by adapting published notations and tablatures. Several different notational types are included, but the set is not supposed to be fully representative or comprehensive; instead, I have attempted to manipulate specific notational features while keeping others constant, allowing the properties of individual notational features to be investigated. Underlying these manipulations is the idea that the best keyboard tablature or general-purpose notation may not yet have been "invented" but may be created in the future by systematically combining notational *features* that have been found to be optimal (Keislar 1994). Space does not permit a complete specification of each notation, but all the features of the notations and tablatures that are relevant to the following discussion should be clear from the figure.

Which of these notations and tablatures might be expected to permit faster and more reliable reading and learning than others? Would some be more efficient because they make more logical or transparent a crucial relationship between the visual image and the musical structure, or between the visual image and the ergonomics of the hands on the instrument?

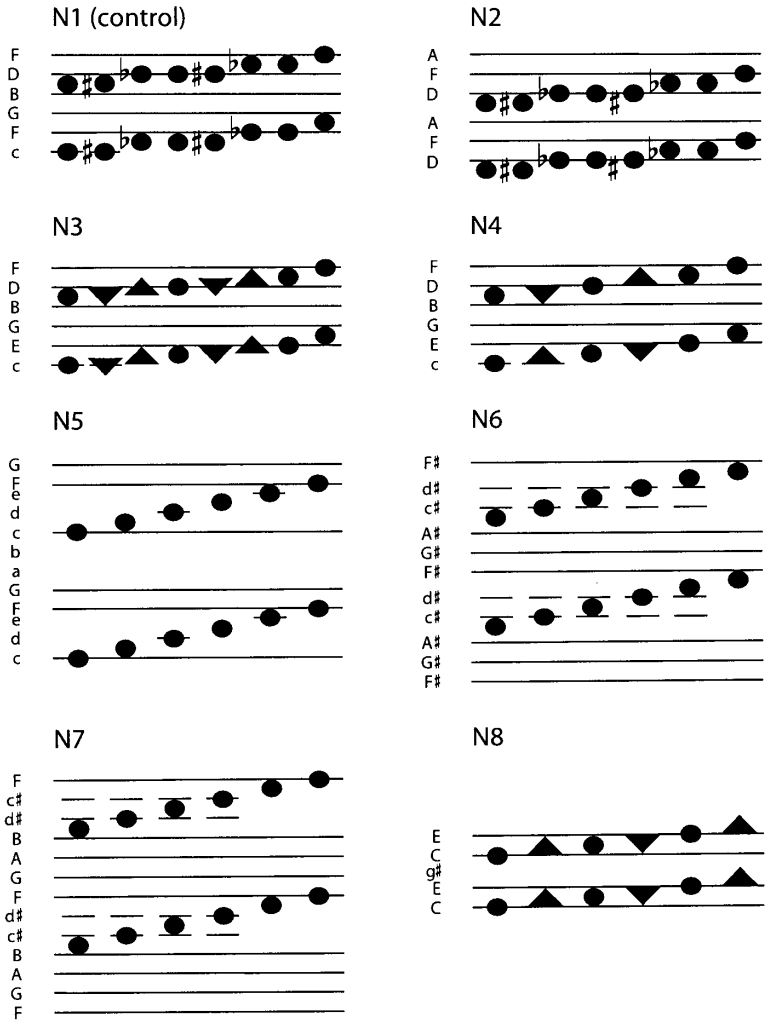

Figure 2. Examples of non-conventional notations and keyboard tablatures for experimental study. For each, a chromatic scale is notated from C to F in octaves. Labels for staff and ledger lines are for illustration only and are not part of the notations.

One way to address these questions is to develop predictions based on specific criteria. In the following, I express such predictions in abbreviated form as "X > Y", meaning that students who use notation X are predicted to sight-read more accurately, learn music more quickly, and to give more "musical" performances after rehearsal, than students using notation Y. Such predictions could be tested by monitoring student progress during a longitudinal study (to be described below).

The first notation in the figure, N1, is the conventional system. It is included as a control with which every non-conventional notation should be compared (to be taken seriously, a non-conventional candidate should at the very least be able to "outperform" conventional notation in an experiment). Notations N2 to N4 each differ from N1 in a single notational parameter; all other parameters are held constant.

N2 is like N1 except that it incorporates octave equivalence. It uses a three-line staff with lines on D, F and A, replicated in each octave register. Historically, D-F-A is the most common diatonic three-line staff (nine examples are referred to by Read 1987). The staff enables the notation of an entire octave register (e. g., C4 to B4) without ledger lines.

One might predict N2 > N1, for two reasons. First, pitch classes in N2 look similar in different octave registers. By taking advantage of the dimensionality of musical pitch, according to which chroma (pitch class) and pitch height (octave register) may more easily be coded separately (e. g., 12 chroma x 5 octaves) than along one dimension (e. g., 60 separate pitches; cf. Bachem 1950, Révész 1912), the notation establishes a cognitive isomorphism with the two dimensions of pitch perception. Second, N2 has fewer staff lines to learn than N1 (3 against 10). Cognitive limitations such as those identified by Miller (1956) may therefore confer a learning advantage on N2.

Notations N3 to N8 do not use accidentals. We might therefore expect N3 to N8 to be easier to read in more complex chromatic music, but more difficult to read in simpler diatonic styles where accidentals alert the reader to deviations from the prevailing scale.

N3 is like N1 except that accidentals (sharps, flats and naturals, including key signatures) are replaced by shaped noteheads. Sharps are represented by downward-pointing (top-heavy) triangles; flats, by upward-pointing (bottom-heavy) triangles. Geometrically, the triangle is the simplest possible symbol that can specify direction (up-down); historically, Read (1987: 425–433) lists 8 proponents of triangular noteheads. The exact pitch of each notehead is intended to correspond roughly to its perceptual center (as studied by Davi et al. 1992, Proffitt et al. 1983).

Duncan (1984) found that two features of the same visual object are generally easier to judge than individual features of two visual objects. One would therefore expect that replacing the conventional notehead-plus-accidental combination by a single symbol would facilitate reading. Two studies have applied this

idea to music notation. First, Kyme (1960) investigated scores in which notehead shape added information on pitch (relative to the tonic: one shape for *do*, another for *re*, etc.). Second, Rogers (1991) investigated scores in which notehead colour indicated pitch (12 colors for 12 absolute chromatic pitches). In both studies, primary school students learning music through the non-conventional notation became better sight-readers than conventional controls. N3 differs from the notations tested in those studies: it is non-redundant (here, notehead shape *replaces* conventional accidentals, rather than *supplementing* them). Under these conditions, one might expect N3 > N1.

N4 is like N3 except that enharmonically equivalent pitches (e. g., C♯ and D♭) are identical. White piano keys are notated by round noteheads; black keys by downward pointing triangles below staff/ledger lines, or upward triangles above lines. The one-to-one correspondence between visual images and piano keys, and relevant data on stimulus-response mapping (Proctor & Reeve, 1990), suggest that N4 > N3.

Notations N5 to N8 differ fundamentally from N2 to N4. In N2 to N4, neighboring vertical positions correspond to successive diatonic notes (C, D, E...); students learning these systems could use them as a stepping stone to conventional notation. By contrast, N5 to N7 are based on the chromatic scale (C, C♯, D...), and N8 is based on the whole-tone scale (C, D, E, F♯, G♯, A♯).

N5 to N8 all incorporate octave equivalence and a one-to-one correspondence between symbol and piano key. N5 was proposed by Parncutt (1984) and has not been further developed or widely applied since then. N6 (Parncutt, 1990; see also Parncutt & Stuckey, 1992) may be regarded as a cross between Klavar and conventional notation; related to numerous other published keyboard tablatures (see e. g. Read, 1987), it is essentially the same as the independently developed Roberts 7-5 staff (Roberts, 1997a, 1997b) with the following exceptions: in N6, vertical distance is always proportional to pitch interval in semitones, whereas Roberts followed the Klavar principle of equally spacing the white keys; and Roberts also made small changes to conventional rhythm notation. N7 (Parncutt, 1996) is an adaptation of Ailler-Brennink Chromatic Notation (Brennink, 1976) produced by shifting the staff through one semitone. It has the same staff and ledger lines as Franz Grassl's notation (Brennink, 1983); again, the two notations were developed independently, and rhythm notation is slightly different in each case. N8 is based on Reed's (1986) Twinline Notation, which emerged from a collaboration between de Vries and Reed (1991). It is also a close relative of Bayreuther's (1985) system. N8 uses full noteheads in the same way as conventional notation, whereas Reed's Twinline uses open noteheads.

Staff and ledger lines in N5 to N8 have been chosen to optimize, in different ways, the mapping between the staff and the piano keyboard, with its 7 white and

5 black keys per octave. In N5, staff/ledger lines correspond to white keys; notes not on lines are black keys. In N6, this relationship is reversed. In N7, notes within the staff correspond to white keys if they fall on lines, and to black keys if they lie in spaces; between staves, the relationship is reversed. In N8, circular noteheads within the staff correspond to white keys and triangular to black; again, the relationship is reversed between staves, where ledger lines (not shown) are used to mark the pitch G♯. These partial isomorphisms between stimulus (score) and response (keyboard) configurations suggest that (N5 to N8) > (N1 to N4).

The ease and efficiency with which students read and learn music written in N5 to N8 may be expected to depend on the following main factors. Analysis of appropriate experimental data should reveal which of these factor(s) predominate:

1. Closeness of correspondence between notation and piano keyboard. According to this criterion, one might expect N6 > N5 > N7 > N8.
2. Clear representation of asymmetric relationship between the familiar C major scale and the chromatic scale, aiding orientation and exploiting the uniqueness properties of diatonicism as expounded by Balzano (1980). According to this criterion, one might expect N5 > N6 > N7 > N8.
3. Maintenance of space between staves, to minimize clutter (visual noise caused by distractors close to visual targets). According to this criterion, one might expect N5 > N8 > N6 > N7.
4. Minimization of the number of staff and ledger lines whose pitches need to be learned. According to this criterion, one might expect N8 > (N5 and N6) > N7.
5. Use of equally spaced staff/ledger lines (as in conventional notation). This clarifies notehead positions relative to lines, especially in poorly printed or hand-written scores. According to this criterion, (N7 and N8) > (N5 and N6). (Note that, unlike *Klavar*, N5 to N8 all have a chromatic-proportional pitch axis, preserving proportionality between vertical spacing of notehead centers and pitch intervals in semitones.)
6. Clear representation of the spatial or graphical relationships between noteheads. A notation with a chromatic-proportional pitch axis and identically shaped noteheads preserves the shapes of chord types as they are transposed, so that, for example, close-position root-position major triads look the same in different transpositions, and different from minor. This is especially advantageous in more tonally complex music. Notehead overlap becomes a problem when N8 is used to notate chords in close voicings. According to this criterion, one might expect (N5 to N7) > N8.

To avoid confounds, all eight notations are intended to have the following properties in common. It would be important to keep maintain these commonalities in a controlled experimental test:

1. a continuous staff (like a conventional "great staff") covering a four-octave range from C2 to C6;
2. conventional bass and treble clef symbols centered on G4 and F3 respectively;
3. conventional rhythm notation (Several of the notations in Fig. 2, especially N7 and N8, might benefit from the additional cue of open noteheads for white keys and full noteheads for black keys, as in *Klavar*; but this would require a change in rhythm notation, and a careful examination of non-conventional rhythm notations is beyond the present scope. Another possibility would be to use open noteheads for the prevailing scale represented by the key signature in conventional notation, and full noteheads for non-diatonic notes; a change of key could be indicated by a double bar as in conventional notation.);
4. horizontal spacing of notes as in conventional printed scores: neither proportional to time nor equally spaced, but between the two (British Standards Institution 1982); and
5. controlled layout of notes on the page, including the number of lines of music and of measures per line; positioning of slurs, phrase markings, and other instructions; and the direction of note-stems.

9 Proposed Experimental Method

To assess and compare the psychological efficacy of a set of notations such as those in Figure 2, one might carry out a longitudinal study in which beginner pianists, each using a single notation, learn the piano within a standardized training programme. The primary aim would be to monitor the acquisition of basic musical skills, such as sightreading and expressive performance, and compare them across notations.

Each student would learn the same series of pieces, so performances could be compared. Because some pieces are easier to play in some notations than others – e. g., a piece on black notes would be easier to read and play in *Klavar* than in *Ailler-Brennink* – the repertoire would need to chosen carefully so that, averaged over all pieces, it "matched" each notation system about equally well.

The students in a first study of this kind should probably be limited to adult beginner pianists. They should be adults, because children are unable to provide fully informed consent; adults can learn music as quickly and successfully as children, provided they find the time to practice (Orlofsky 1997). They should be beginners, to avoid negative transfer – cognitive interference with notational parameters learned from the conventional system. (Note that it is not yet feasible to contemplate testing the usefulness of keyboard tablatures for higher-level

performers; this would need to wait until a hypothetical future date when a large number of beginners are using tablatures of different kinds.) Finally, students should learn piano or keyboard (rather than some other instrument or voice) because of its popularity and flexibility, and the relatively high rate of information typically processed by pianists when sight-reading.

Students would only be accepted for the project if they had tried to learn music in the past and given up for reasons that include reading difficulties. They would be asked to declare that they had already given up the possibility of becoming fluent readers of conventional notation. They would be offered the opportunity to learn the piano using a notation or keyboard tablature that, for well-documented and psychologically based reasons, was predicted to be easier to learn and use than conventional notation. Notations would be assigned to different students at random. Lessons would be offered at a nominal fee (the same for all students), adjusted to maximize students' motivation to work consistently; teachers would be paid partly by students and partly by the project.

The teachers on the study would be experienced teachers of piano to adult beginners, and have some knowledge of, and interest in, non-conventional notations. Each teacher might, for example, take eight students, one for each of the notations in Figure 2. Individual teachers would inevitably be biased toward some notations and against others; to avoid such biases affecting experimental results, teachers would avoid talking about rules of notation in lessons. The rules of each notational system would instead be described in separate documentation, supported by an independent telephone help-line. The teacher would merely demonstrate which notes to play at the keyboard, and how to play them. Teachers would therefore need to know all the pieces from memory (not hard at beginner level).

10 Subsidiary Experiments

The illustrated notations may also be tested for their effectiveness as carriers of information, regardless of the use to which the information is to be put. Two such aspects of a notation's effectiveness are its *spatial memory facilitation* and its *compactness*.

Spatial memory facilitation may be defined as the degree to which a background grid (here, a musical staff) helps a reader to remember the positions of a pattern of dots, regardless of the dots' meaning. It is the effectiveness of a grid as a visual frame of reference for short-term recall.

Sloboda (1976) tested the spatial memory facilitation of the conventional five-line staff. The same method could be used to compare spatial memory facilitation across different notations. Observers (not those taking part in the main longitudi-

nal experiment) would see a pattern of dots (quasi noteheads) against a grid of lines (one of the musical staves to be tested) on a computer screen. After a short time, the noteheads would disappear, but not the staff. The observers would attempt to recreate the pattern (using a mouse), or match it to other patterns. Notations in which staff and ledger lines are equally spaced (N1 to N4, N7, N8) might be expected to facilitate spatial memory by comparison to the others (N5, N6).

Compactness may be defined as the amount of usable or visible information that can be represented per unit area. Conventional notation is clearly very compact, integrating a large amount of information into a small space (Read 1974, Sloboda 1981). Notations N3 to N8 in Figure 2 are more compact than conventional notation in the horizontal dimension, due to the absence of accidentals, but less compact in the vertical dimension, due to the larger number of lines and spaces available on the staff. In the absence of experimental data it is not clear a *priori* how these two elements may be weighed up against each other to arrive at an overall measure of a notation's compactness.

One way to measure the compactness of a notation would involve its psychophysical *threshold of perceptibility.* To determine this experimentally, the image of a piece of music would be scaled down (while preventing the reader's head from moving closer to the computer screen) until a significant deterioration occurred in reading accuracy, or a significant increase in response times. Of the illustrated notations, N8 would appear to be most compact. One would therefore expect more information to be legible in N8 in a given area of score than in the other notations.

A similar method could be used to establish how far apart noteheads should be spaced horizontally, by comparison to vertically, for maximum compactness and legibility, and how far apart they should be spaced relative to distances between staff lines. This could be done first for each notation independently, before evaluating the overall compactness of the notation.

11 Applications

The results of the project outlined here could benefit adults wishing to learn to play the piano who have tried and failed to learn conventional notation – whether for social, psychological or medical reasons – and have access to computer hardware to support software for automatic transcription of conventional scores.

The findings might have significant implications for music education. The data obtained in the described experiment could improve understanding of the role of notational systems in assisting perceptual-motor learning in music prac-

tice, leading to optimization of music teaching methods for rapid progress in instrumental learning.

An important group of beneficiaries might be the mildly learning disabled. The therapeutic benefits of music performance for people with learning disabilities are well known. Dyslexics are more likely to acquire music reading skills if presented with a more straightforward notation system. Similarly, a standardized keyboard tablature could be applied in music therapy.

Standardization of a single keyboard tablature would stimulate the music publishing industry. An accepted tablature would allow the industry to tap the considerable market of adults and children who give up musical instruments for reasons including reading difficulties.

Finally, the findings of the proposed experiment may play a role in the longer-term development of a general-purpose, chromatically based alternative to conventional music notation.

12 Summary and Discussion

I have attempted to develop a comprehensive theoretical framework for the design of music notation systems that is based on perceptual-cognitive principles, comprises a number of distinct criteria (cf. Johnston et al. 1996, Keislar 1994), and allows predictions of differential efficiency of these systems to be derived. Summarizing, the following criteria may be expected to affect the relative psychological efficiency of different non-conventional notations for keyboard:

- Incorporation of octave equivalence
- Use of one symbol for each pitch (no accidentals)
- One-to-one correspondence between pitches and notes (no enharmonics)
- Clarity of spatial relationships between noteheads (proportional pitch axis)
- Space between staves; absence of "clutter" or visual noise
- Visual discriminability of symbols (unlikely to be confused with each other)
- Small number of staff and ledger lines
- Correspondence between notation and piano keyboard
- Representation of asymmetrical relationship between diatonic and chromatic scales
- Compactness

The following criteria are harder to address experimentally, but should also be taken into account when designing keyboard tablatures:

- Non-confusability with conventional notation. A tablature that is easily confused with conventional notation is unlikely to co-survive with it. (N7 could encounter this problem because its four-line staff is similar in appearance to the conventional five-line staff.)
- Non-arbitrariness of choice of staff and ledger lines. A notation is easier to standardize if the pitches of staff and ledger lines are determined by a simple rule. (According to this criterion, N7 may be considered superior to *Ailler-Brennink Chromatic Notation.*)

The various features of notation systems tend to be so tightly integrated that improving on one aspect inevitably affects other aspects. For example, a good piano tablature may make reading easier and quicker than conventional notation in the case of complex chromatic music, but an experienced sight reader may still find conventional notation easier in simpler diatonic styles, where conventional notation clearly indicates deviations from the prevailing diatonic scale represented by the key signature. In this light, perhaps none of the notations presented here can necessarily represent a clear all-round improvement on conventional keyboard notation. It will not be possible to know whether a notation is clearly and generally better than conventional notation until a large number of musicians are fluent in it.

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